

DETERMINANTS OF LAND ALLOCATION IN A MULTI-CROP FARMING SYSTEM:  
AN APPLICATION OF THE FRACTIONAL MULTINOMIAL LOGIT MODEL  
TO AGRICULTURAL HOUSEHOLDS IN MALI

By

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## ABSTRACT

### DETERMINANTS OF LAND ALLOCATION IN A MULTI-CROP FARMING SYSTEM: AN APPLICATION OF THE FRACTIONAL MULTINOMIAL LOGIT MODEL TO AGRICULTURAL HOUSEHOLDS IN MALI

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Effective food security work in developing countries, such as Mali, relies on a thorough understanding of the rural farming system. A common approach is to study land allocation decisions to specific crops. In accomplishing this, one challenge is to model all production outcomes in a multi-crop system. This thesis attempts to overcome this challenge in order to study the determinants of how much of a household's cultivated land it allocates to cotton, maize, sorghum, millet, and secondary crops. First, incorporating insights gained by the author while serving as Peace Corps Volunteer in Mali, the agricultural household model helps to identify factors that explain land allocation to various crops. This framework is applied to survey data from seven villages in Mali's Koutiala production zone. A fractional multinomial logit econometric model is used to estimate the effect of household and production attributes on shares of cotton, maize, sorghum, millet, and secondary crops simultaneously, the results of which are presented as average marginal effects. Among other results, the analysis shows that ethnic groups not native to the Koutiala area are associated with significantly smaller shares of maize, and that villages with better market access are correlated with much higher shares of millet and smaller shares of maize, sorghum, and especially cotton. These results, along with personal experience, inform recommendations for policymakers, such as the need to reduce transaction costs for coarse grain markets, promote maize and secondary crops as nutritious and marketable goods, and remain mindful of remote villages during the restructuring of Mali's cotton industry.

This thesis is dedicated to the people of Simona.  
*Ala k'a suman tige nyuman di aw ma, sisan ani waati be.*

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## CHAPTER 1: INTRODUCTION

### 1.1 Problem Statement

Comprehending farmers' land allocation decisions is a significant challenge within the field of agricultural economics and has thus been the subject of many studies. This is because various factors, including transactions costs, risk aversion, and household preferences are incorporated into the decision-making process. It is further complicated in developing countries, such as Mali, a land-locked West African country where households are largely subsistent, face greater market obstacles, and often grow three or more crops. Yet, serving as a Peace Corps Volunteer in Mali from July 2010 to April 2012, I was to see first-hand, living in the rural village of Simona, how important it is to understand the complexities of farming systems in order to engage in effective agricultural development work. Certainly, in a country where 70 percent of the population relies heavily on rain-fed agriculture for their livelihoods, it is critical that policymakers understand how and why farmers devote certain shares of their land to growing cotton, maize, sorghum, millet, or other field crops.

Therefore, this thesis aims to develop a relevant model and test it using empirical data from the historical cotton basin of Mali's southern-most Sikasso region, which can benefit policymakers as they attempt to improve household food security. Indeed, the region has long struggled with food insecurity despite being "the breadbasket of Mali," with poverty rates 30 percent higher than any other region (USAID 2010).<sup>1</sup> With a poor growing season in 2011 largely due to drought, a still unresolved civil unrest, and current threats of locust swarms, it is almost certain that both short- and long-term interventions will be needed to diminish household

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<sup>1</sup> The phenomenon is known as the paradox of Sikasso and is discussed at length in Delarue et al. (2009).

food insecurity in the future. Understanding how certain factors affect crop allocation of coarse grains and other crops can lead to more effective, evidence-based strategies.

Moreover, many households in Sikasso are dependent on Mali's cotton industry, which is managed by a 98-percent government-owned monopsony known as the Malienne Compagnie de Developpement des Textiles (CMDT) (Mali Agricultural Sector Assessment 2011, henceforth, Mali Assessment). In Simona, the village where I served as a Peace Corps Volunteer, cotton production served as the main income-generating activity for 96 percent of households. Also, CMDT provides improved access to credit and coarse-grain inputs for many villages, especially in remote areas. However, due to debt worth approximately two hundred million US dollars that accumulated between the 2004/05 and 2008/09 seasons, negotiations have been underway since early 2010 to privatize CMDT into four companies, though recent bumper crops and current civil unrest makes this deal uncertain. Still, given the significant effect that CMDT and its policies have on its suppliers, both CMDT and Malian policymakers can benefit from understanding the relationship between cotton and coarse grain production, whether CMDT restructures or not.

In order to address these concerns, this thesis poses the following research question: Which market and household characteristics significantly affect land allocation of cotton, maize, sorghum, millet, and secondary field crops? In other words, what determines how much of a household's land it devotes to specific crops? Not only will answers to this question give insights to Malian policymakers as they try to tackle complex problems in the Sikasso region, but perhaps more importantly, the development of an econometric method that does so will equip economists to evaluate land allocation decisions in multi-crop farming systems under other circumstances where it could assist in addressing similar issues.

## 1.2 Literature Review

There is a rich literature dedicated to studying determinants of supply response, crop selection, and land allocation in developing countries, which were reviewed for this study. The first set stemmed from the Nerlovian supply model, which originates from Nerlove (1956) but has been expanded and modified upon since. Askari and Cummings (1977) state that, in basic terms, the model estimates a household's agricultural production in terms of price expectations as a function of past prices as well as partial area adjustments, though it does include a vector of non-price factors that may affect supply response. In a sense, it attempts to model present supply as a function of past supply, which can be effective for forecasting.

Indeed, it has already been adopted to study the cotton industry in Mali; for example, Theriault (forthcoming) examines the effect of CMDT institutional variables on cotton supply over a decade. She finds that timely payments by CMDT and higher credit recovery rates had a significant positive effect on future cotton supply. Yet, because the study focused on this one crop, it does not explore how these institutional variables affected cotton's relationship with coarse grains. Considering four Malian crops, Vitale, Djourra, and Sidibe (2009) estimate supply response over 14 years while controlling for crop rotation, finding that Malian producers' responses to output prices are nearly twice as inelastic as those of producers in developed countries. Still, because their dependent variables are expressed as acreages and not shares, their work struggles to show changes in one crop relative to another. Understanding this relationship is essential as land and other production constraints limit the amount of resources that can be devoted to multiple crops.

While it has its strengths in certain applications, the Nerlovian model will not work to answer the research question put forth by this thesis. From a practical viewpoint, the Nerlovian

model requires time-series data that are not available for this study. Also, its theory of partial adjustment may not be fitting for Mali; as will be discussed, many farmers have dropped cotton production altogether in certain years—a change that is hardly partial. Furthermore, the assumption of the Nerlovian model that farmers will tweak their past production based on present circumstances does not fully model the foundations of household decision-making. It is better to attempt a model that rationally explains how farmers might annually re-evaluate crop choice and land allocation based on developments in market and household characteristics in order to understand decisions made in the past, present, and future.

The need for such a model brings into play a second set of literature, which seeks to model household maximizing behavior and apply various methods of empirical analysis. Its primary working hypothesis is that semi-subsistent households are rational, but do not necessarily aim to maximize profit. This is because these farms are not traditional firms, but as partial consumers of what they produce, they seek to maximize household utility or have multiple objective decision-making problems. To test this theory, studies have employed Cobb-Douglas production functions (De Boer and Chandra 1978; Barnum and Squire 1978), goal programming software and simulations (Lee, Tipton, and Leung 1994), and linear programming (Ahn, Singh, and Squire 1981), finding that these other models are often more effective for explaining rural household behavior than one that assumes profit-maximization. In particular, the agricultural household model (discussed in Chapter 3) has been adopted and adapted to study a wide-scope of issues, including transactions costs and market participation (Omamo 1998; Barrett 2008; Goetz 1992), missing markets (de Janvry, Fafchamps, and Sadoulet 1991; Van Dusen and Taylor 2003), risk aversion (Fafchamps 1992; Hazell 1982), labor availability (Benjamin 1992), and credit access (Dorward 2011) to list a few. These papers and others make

important contributions to economists' understanding of the obstacles facing semi-subsistent households and how such barriers may influence their supply response.

However, because they are set in various countries and often focus on a particular topic relevant within the agricultural household model, the literature as a whole remains incomplete. Additionally, the details and assumptions of these studies have not been discussed in the context of Mali's cotton-growing region; for example, many studies assume the existence of an active labor market, though one is missing in the rural villages studied here. Moreover, most studies take data from a single or dual-crop production system, or simplify crop diversity into two categories—typically cash and staple crops (De Boer and Chandra 2001). Thus, they are often not able to predict crop-specific supply response in a multi-crop system, though production of three or more crops is the norm in Mali and other developing countries. Therefore, while there is wealth of literature on which to draw in designing a conceptual model for Malian households, there is not an analytical technique that satisfies the scope of the research question given that I want to estimate the effect of multiple determinants on a multi-crop system.

A final bit of research should be discussed here as it most closely relates to this thesis's research objectives: current work carried out by the Project to Mobilize Food Security Initiatives in Mali (PROMISAM), a joint USAID/Mali, Gates foundation, and Michigan State University program aimed at assisting Mali's Food Security Commission. One research activity under PROMISAM aims to analyze the relationship between Mali's cotton and coarse grain subsectors and particularly how participation in the cotton value chain affects coarse grain productivity and food security. The hypothesis that the cotton industry may affect coarse grain yields arises from the fact that farmers have improved access to credit and fertilizer through CMDT. Yet, recent PROMISAM field work by Boughton and Dembelé (2010) has noted that Mali is in "a process of

transition from a cotton-cereal production system, where the cotton subsector facilitates access to fertilizer for cereals as well as cotton, to a cereal-based production system.” This is a considerable development, and where true, may greatly reduce the efficacy of interventions through CMDT designed to improve farm productivity.

Following this report, scholars associated with PROMISAM analyzed survey data from Mali’s cotton-growing area (the same data used for this thesis, described in Chapter 4). In another thesis, Sako (forthcoming) is exploring the determinants of participation in the cotton industry—whether or not a household grew cotton—across the three survey rounds. Additionally, Murekezi et al. (forthcoming) is updating evidence on the interactions between cotton and coarse grain production, last analyzed quantitatively by Dioné (1989). Estimating the effect of cotton area on the quantity of fertilizer applied to each coarse grain, and then the effect of that fertilizer on productivity, Murekezi et al. find that participation in the cotton industry is associated with higher levels of fertilizer use, which significantly increases maize yields. This is an important verification of the perceived relationship between cotton and maize production in Mali.

Since both these upcoming studies focus on distinct, albeit important, aspects of Mali’s multi-crop system in the cotton basin, it would be beneficial to analyze the farming system as a whole. Not only may doing so challenge or reaffirm their findings, but it may also detect unintended consequences of cotton production or policy interventions. For example, participating in the cotton industry may improve fertilizer use and maize productivity, but does it improve land allocation to maize or other coarse grains as well? After all, dropping cotton frees up a certain set of constrained household resources—land, labor, and capital—allowing farmers to plant more hectares of coarse grains and spend more time cultivating coarse grains (or other food

crops), leading to increased production levels. On the other hand, as many think, dropping cotton production potentially limits access to other constrained resources that can be secured with credit through CMDT, such as fertilizers and insecticides, preventing farmers from maintaining coarse grain production levels, particularly for maize, which relies more on chemical inputs. Or finally, these factors could have counteracting effects that lead to insignificant changes in household coarse grain production as a result of growing cotton, depending on a household's wealth and access to markets. Thus, given the importance of such findings for policymakers, there is room for a similar study on these topics using a different approach. After all, the dynamics of farming systems are too complex to be fully explained by any one study, including this thesis.

This example not only stresses the complexity of resource allocation in a multi-crop system, but also brings up another critical aspect of farmer's decision-making for production: though decisions are made continuously throughout each growing season, the rational farmer makes decisions after considering all crops simultaneously. Accordingly, one cannot assume that farmers decide to grow cotton first, notice improved access to fertilizer, and then decide to grow maize, because this assumes a sequential decision-making process that may instead be simultaneous. Perhaps some farmers grow cotton because that makes it more affordable to grow maize, and so on. While Murekezi et al. (forthcoming) address this simultaneity bias using an adapted control function approach with instrumental variables, another alternative would be to develop a method that explores the relationship between production decisions without treating a single crop's planting decision as an independent variable that explains another crop's planting decision. Such a technique could potentially enrich and augment PROMISAM's current findings as well as be applied to other contexts if it proves to be an effective estimator.



### **1.3 Research Methods**

A review of the existing literature reveals unsolved puzzles, and a few gaps where this thesis hopes to make some contributions. The first is an agricultural household conceptual model discussed and fitted to the context of farmers in Mali's Cotton Basin. Rather than assuming each household farm acts like a profit-maximizing firm, the agricultural household model sees each farm as a family with a utility-maximization problem. The primary implication contrasting these two maximization assumptions is that as a utility-maximizing unit, the tastes and preferences of the household are incorporated into its own production decisions. The utility-maximization problem is then subject to resource constraints for income, time, and production. The constraining effect of high transaction costs that occur because of missing markets is also a key factor in the model.

The framework proposed from the agricultural household model will then inform the selection of variables from available sources. These data come from two survey rounds of about 150 households—25 from six villages—from the Koutiala cercle in 2008/09 and 2009/10. Fifty households are also added to the sample from one round of surveys in 2010/11. These data originate from one village (i.e., Simona in the Yorosso cercle) where I served as a Peace Corps Volunteer. In total, this gives our dataset 350 observations on which to draw for the analysis.

Next, these data will be used to estimate a fractional multinomial logit econometric model, which will simultaneously estimate changes in shares of total farm land allocated to staple crops as a function of market and household variables. Using an approach formalized by Papke and Wooldridge (1996), a standard logit model, which is typically used to generate predicted probabilities for binary outcomes, will be used instead to fit predicted crop shares to actual crop shares. Thus, by modeling shares of all crops as outcome variables, I avoid the risk of

a simultaneity bias associated with including one crop's production decision as an explanatory variable for another crop's production decision. Using the coefficients generated from the fractional multinomial logit through a quasi-maximum likelihood estimator, I will calculate the average marginal effects of the explanatory variables on crop shares.

To my knowledge, this thesis will be the first use of this econometric technique to study multi-crop system land allocation decisions. It better recognizes the complexity of the decision and also is able to predict shares for all crops simultaneously. Doing so will contribute to related literature where the household decision-making model is oversimplified or where the analytical focus on a single crop in a multi-crop system neglects to account for trade-offs or synergies between crops.

## **1.4 Thesis Organization**

The remainder of this thesis will proceed as follows. Chapter 2 provides context for the issues in this paper by describing the farming system in Mali's Koutiala production zone based on CMDT data and observations attained as a Peace Corps Volunteer in Mali. Chapter 3 then presents the agricultural household model, a conceptual framework for determining which factors affect crop choice and resource allocation. Chapter 4 describes the data and identifies the variables for the empirical application of the model. Chapter 5 defines the fractional multinomial logit and then presents and discusses its results. Finally, Chapter 7 concludes.

## **CHAPTER 2: BACKGROUND**

This chapter increasingly narrows its discussion of Mali in the context of this study. It describes the Koutiala production zone where the research was conducted and provides an overview of Koutiala's staple crops, their subsectors, and possible synergies between them. Informed by PROMISAM research, CMDT data, and personal observation, the chapter's aim is to provide background for those unfamiliar with the Koutiala production zone in Mali. A detailed description of the typical household found in the Koutiala area is also provided in Appendix 1.

### **2.1 Geographic Scope**

Mali is a land-locked country in West Africa, nearly twice the size of Texas, which lies east of Senegal and north of Cote d'Ivoire (CIA 2012). It has a population of about 16.5 million people, though 90 percent of the population lives in the southern half of the country. This is because the north-eastern regions are located near or in the Sahara desert with a few major settlements along the Niger River, though at the time of this writing, this area is occupied by rebel forces. Both rainfall and population density increase as one travels farther south, so it is no surprise that in the southern-most region of Sikasso, which is highlighted in Figure 1, nearly all rural households are largely reliant on rain-fed agriculture (USAID 2010).

The government of Mali has a four-tiered administrative system. Its eight regions are overseen by the capital district of Bamako, and each region is divided into cercles. Figure 2 shows that the Sikasso region is split into seven cercles, each of which is subdivided into smaller communes. Finally, communes are comprised of several rural villages that are traditionally run by village chiefs, not part of the formal administration. For example, I served as a Peace Corps Volunteer in Simona, which was one of twelve villages in its commune in the Yorosso cercle.

**Figure 1: Map Highlighting Mali's Sikasso Region (Profoss 2011)**

For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.



**Figure 2: Cercles of the Sikasso Region (Rarelibra 2006)**



Given its size and economic importance, the cotton company CMDT has its own administration consisting of six production zones, four of which cover the Sikasso region. While this thesis's results may be applicable to all cotton-producing regions in Mali, its data only come from one of the CMDT production zones. The Koutiala production zone covers Sikasso's Koutiala and Yorosso cercles, located to the upper right of Figure 2. The Koutiala cercle consists of 35 communes, while neighboring Yorosso cercle only manages 9. Geographically, the two cercles are very similar, with the Yorosso cercle being higher elevated and generally more isolated from economic activity. The city of Koutiala itself, despite not currently serving as a regional capital, is Mali's third most populous city. Located in the "Old Cotton Basin" and at crossroads between Sikasso, Burkina Faso, and roads to the Niger River, it is a regional trade hub with a strong industry in cotton manufacturing. Since this production zone is historically the most significant producer of cotton in the country, it makes sense to focus here given the relevance of cotton to Mali's economy and to the research question.

This chapter will place greater emphasis on Simona, the village in which I served for two years as a Peace Corps Volunteer, as a case study for a rural community in the Koutiala production zone. This means that while the information presented is applicable to most Malian households in this area, Simona can serve as a concrete example and reference point. Qualitative information about Simona comes from personal observation or informal interviews with various local farmers, while any quantitative data were collected by a survey of the 2010/11 production cycle conducted in May of 2011 in which 50 out of Simona's 140 households were randomly selected to participate. Since this dataset is also used in our econometric analysis, Chapter 4 provides a more detailed description for how the data were collected.

Some aggregate data for the Koutiala production zone are also presented in this chapter to describe average crop adoption and shares. While the econometric analysis will incorporate PROMISAM survey data from six villages in the Koutiala cercle, this information will not be presented here. Rather, to get more complete data that also include the Yorosso cercle, I will examine information brought together by CMDT's regional Koutiala office. Statistics and counts of producers are compiled on a yearly basis through CMDT thanks to their network of producer organizations, extension agents, and district offices. Much of these data are collected not only for statistical purposes, but also to order inputs and set the cotton producer price.

## **2.2 The Farming System in the Koutiala Production Zone**

Farming systems research is defined by its focus on the interactions between the production of different crops at the farm-level (Boughton 1994a). In Mali, the portfolio of crops that characterize a farming system vary across regions. For example, in CMDT's Koutiala production zone the standard portfolio includes cotton, maize, sorghum, millet, and some secondary crops, such as peanuts, cowpeas, sweet potatoes, or vegetables. However, just north of the Yorosso cercle, where CMDT is not present, the standard crop portfolio includes fonio, but not cotton or much maize. Understanding a village requires knowledge of its farming system and the agricultural subsectors in which it is involved.

For this study, we are particularly interested in the interactions during the planting phase of the production cycle. The start of this cycle normally occurs in late April, when planting potentially begins, and goes to late May and June, when households face a final decision for crop choice and land allocation. This time is important as it defines the break between agricultural cycles; so, when it is stated that data are collected for the 2008/09 agricultural cycle, this means that these crops were planted, grown, and harvested in 2008, but represent the household's

supply of crop (whether it is consumed or sold) throughout 2009. The following subsections intend to explain the characteristics of each crop subsector and how these may influence planting decisions.

### *2.2.1 Cotton*

Today, Mali's cotton subsector is controlled by CMDT (Compagnie Malienne de Développement des Textiles), a cotton monopsony that manages most aspects of input procurement, cotton production, processing, and marketing. It is highly centralized and has been since its development from a French cotton parastatal in 1974 (Tefft 2003). Yet CMDT also retained its economic and social objectives: cotton production as well as building capacity through farmers' organizations, agriculture extension, and functional literacy programs. Furthermore, CMDT has provided farmers with oxen, donkeys, plows, and carts, which are all heavily utilized in crop production today, and moreover, introduced many farmers to maize during the food crisis in the 1970s. For these reasons, many farmers in the Koutiala area appreciate CMDT, though the cotton industry has struggled in the past decade.

Volatile year-to-year world cotton prices and a fluctuating exchange rate of the West African franc (FCFA) to the US dollar have forced the cotton producer price-setting board to balance between farmer livelihoods and CMDT's profitability, with little success. Lower prices have led to decreases in the number of cotton producers and hectares cultivated, which have resulted in cotton production levels in 2007/08 that were only 40 percent of those a decade earlier in 1997/98. The decline also created debt for CMDT over the five years that began in the 2004/05 season and ended in the 2008/09 season; CMDT's total deficit—even after payments from a support fund—was well over a hundred billion FCFA or about two hundred million US dollars (Mali Assessment, 2011). To make matters worse, late payments to farmers and evidence

of corruption have generated distrust among farmers, causing a major cotton strike in 2001, which led to reforms, and a smaller strike in 2008. Because of these struggles, the government of Mali has been working over the past five years to privatize CMDT and splitting it into four separate companies, each of which will have state-protected monopolies in different parts of the country (Theriault and Sterns 2012).

Despite these troubles, the rise in cotton prices over the past few years has the potential to reignite enthusiasm for the cash crop's production among rural farmers. After the strike in 2007/08, the cotton producer price rose to 200 FCFA per kilo, but then dropped to 170 FCFA and 185 FCFA per kilo in 2009/10 and 2010/11, respectively (Mali Assessment 2011); these are the years examined in this study. Since then, the producer price of cotton rose 38 percent to 255 FCFA per kilo in 2011/12, and this price was maintained for the 2012/13 season (ACP Cotton 2011; ACP Cotton 2012). Despite civil political turmoil, these higher producer prices are likely to boost land allotted to cotton throughout the Koutiala production zone.

Aside from the potentially volatile producer price for cotton, participating in the cotton industry has many pros and cons. Cotton is a labor- and input-intensive crop that offers its producers unique incentives through CMDT. Living in the Koutiala production zone means that evaluating the trade-offs between the costs and benefits of cotton production is a decision that every rural households must make. While some decide that it is too risky or not profitable enough, other households are dependent on cotton production, especially in remote areas. In Simona, where 96 percent of households grow cotton, one farmer told me: "Ni kouri te, fen te"—without cotton, we have nothing.

The perks to growing cotton are tied to the institutional design of CMDT and are aimed at reducing direct and indirect costs associated with production, marketing, and risk management.



To start, a legal mechanism established in 1994 requires that CMDT set the farm-price of cotton before each agricultural cycle, and this has been guaranteed thus far. Even though farmers must order their cotton seed, fertilizer, and insecticide around October of the previous year—before they have even harvested their cotton—knowing the cotton price before planting allows households to adjust production decisions, and it reduces their vulnerability to price shocks. Then, once the harvest is completed, CMDT is capable of paying farmers shortly after the raw cotton is collected and delivered to its processing facilities. This gives farmers the cash needed to pay back loans and their children’s school fees without having to sell their coarse grains early, when supply of coarse grains is high and prices are low. This possibly explains the correlation between cotton producer strikes in 2001 and 2008 and complaints of late payments from years prior.

Another important advantage of growing cotton is that it can help farmers procure inputs on credit backed by future cotton revenues. As of 2010, farmers could receive credit annually for up to 74,125 FCFA (roughly 150 US dollars) per hectare of cotton to procure their cotton variable inputs (e.g., fertilizer, seed, and pesticide) as well as fertilizers for coarse grains. This amount is then deducted from the payment for the next cotton harvest along with a small premium. With a premium of only seven percent for purchasing sacks of fertilizer on cotton credit, this input procurement method is preferred by many households in Simona, as described in Appendix 2. Furthermore, CMDT occasionally partners with Mali’s agricultural development bank, the Banque Nationale de Développement Agricole (BNDA), to help farmers purchase livestock on cotton credit over a longer period of time.

Finally, CMDT covers transportation expenses for collecting the raw cotton by sending trucks into the rural villages with the expectation that producer organizations will load their own

cotton into each truck. CMDT will also send trucks to deliver purchased seed and fertilizer. This is noteworthy considering that one Simona farmer recalled his grandfather walking 100 kilometers to Koutiala to sell his cotton to CMDT forty years ago. This collection and delivery service decreases transportation and transaction costs for households, especially those in remote areas, which is often a barrier to relying on other cash crops for income generation.

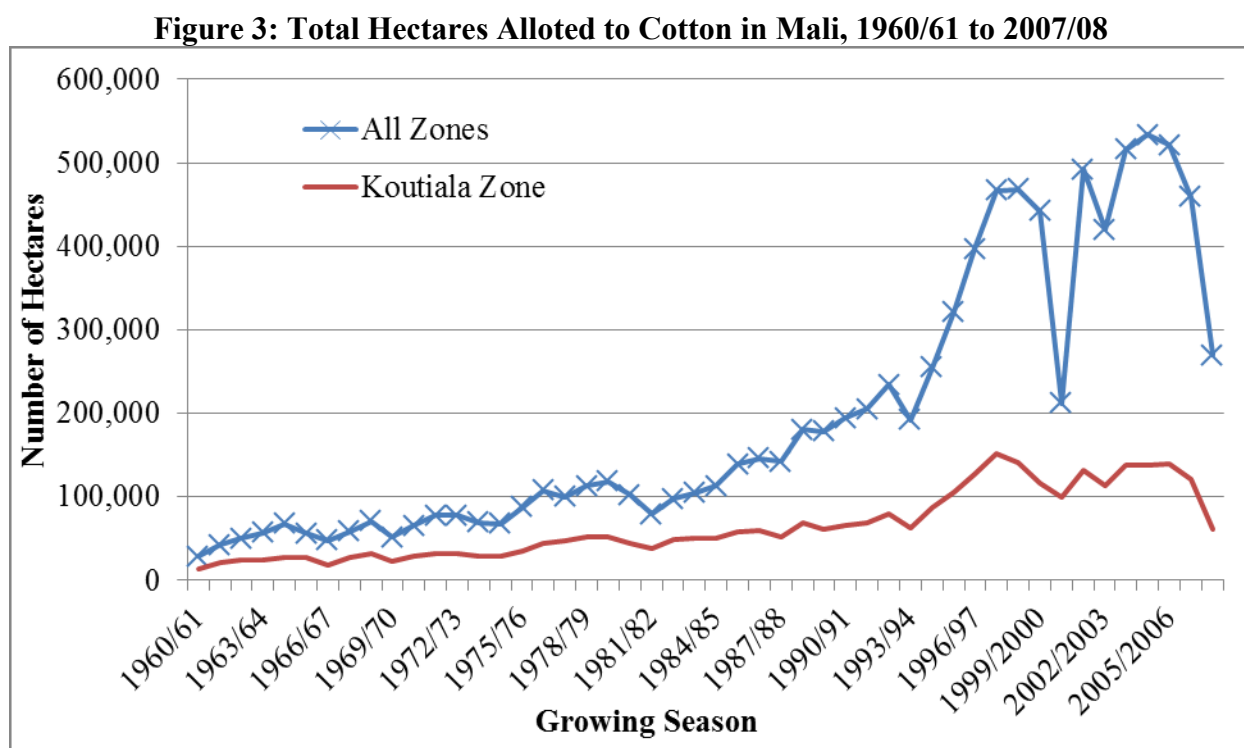
However, cotton has higher investment costs than the other field crops. Seed, fertilizer, and insecticide and must be applied close to their specified quantities provided by CMDT extension agents in order to attain the highest quality. For example, extension agents say that a household should apply three 50 kilogram sacks of Complexe Coton and one 50 kilogram sack of Urea per hectare of cotton as well as spray insecticide on their cotton fields three times.<sup>2</sup> Cotton also requires a lot of family labor, especially at the harvest, when it is not uncommon to see entire households, including women and children, working all day in the stifling heat, picking cotton with their bare hands. There are also factors that cannot be controlled, such as rainfall, which must come early enough to give the cotton time to grow but then stop so that the budding cotton flowers will remain dry until plucked. In 2010, the rains in Simona overstayed their welcome and a lot of healthy cotton began to mold before it could be harvested. Finally, cotton is tough on the land and drains nutrients from the soil, which can lead to fallow fields over time. Thus, when households find an alternative income-generating activity that is less risky and more sustainable, they may be likely to turn away from cotton.

Below, Figure 3 uses CMDT data to chart total hectares devoted to cotton in the Koutiala production zone and all zones between 1960/61 and 2007/08. For the first two decades following Mali's independence in 1960, the Koutiala zone represented roughly half of cotton

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<sup>2</sup> A detailed description of fertilizer requirements for cotton farmers is provided in Appendix 2.

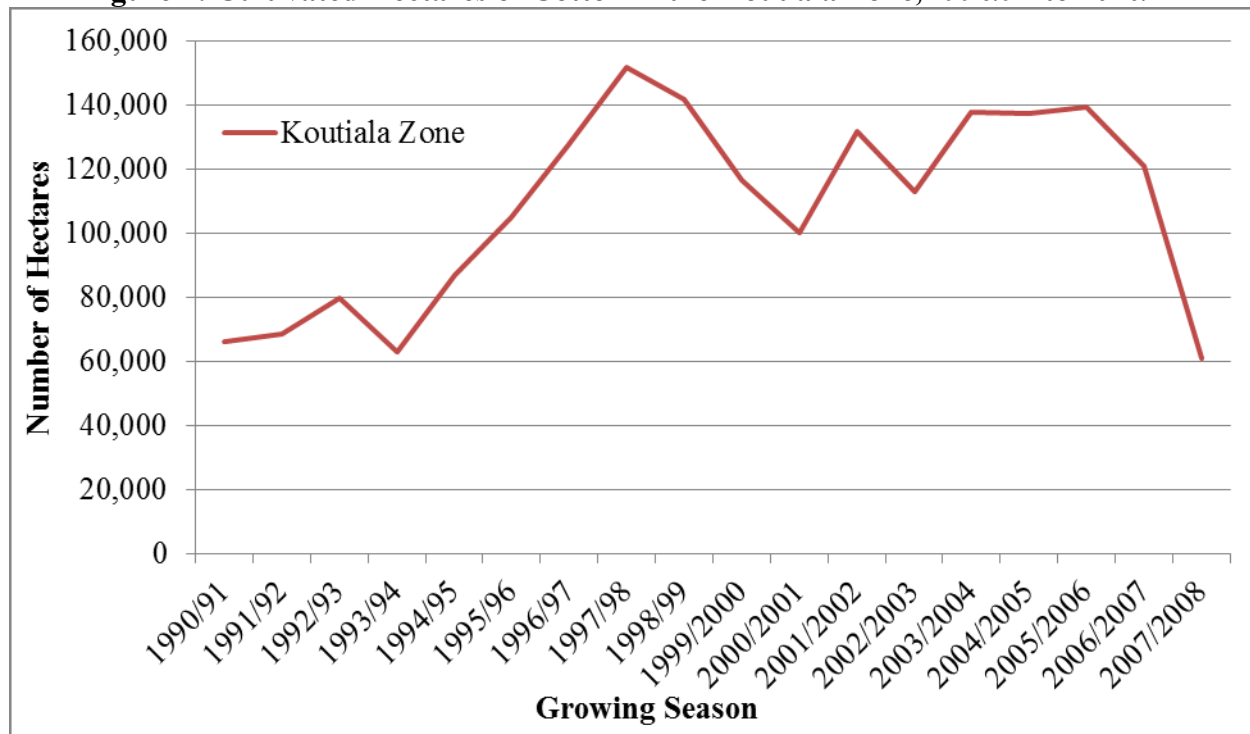
hectares planted in Mali. However, this percentage fell as CMDT expanded to other areas. Figure 3 also shows the effect of the protests in 2000/01 and then 2007/08, especially in other production zones.



*Source: Author's manipulation of data from CMDT, Koutiala Regional Office*

Next, Figure 4 zooms in on cotton hectares planted in Koutiala since 1990/91 and extending to 2010/11. This figure shows the volatility that has defined the past two decades of Mali's cotton industry in Koutiala, whereas before it appears to have been characterized by slow but reliable growth. The figure shows a strong increase in cotton hectares beginning in 1994, after CMDT was mandated to establish a guaranteed pan-territorial producer price and the FCFA currency was devalued. Production then peaked in 1997/98. Additionally, the figure shows that the protests in 2000/01 were not as influential in Koutiala, but did cause a significant decline in 2007/08. The data used for this thesis come from the three years after this strike, as cotton producers have slowly returned to the cotton industry.

**Figure 4: Cultivated Hectares of Cotton in the Koutiala Zone, 1990/91 to 2010/11**



*Source: Author's manipulation of data from CMDT, Koutiala Regional Office*

It was mentioned previously that 96 percent of Simona households grew cotton in 2010/11, but is this percentage the same across the entire production zone? In the six villages that PROMISAM surveyed from the Koutiala cercle—the details of which are described in Chapter 5—the fraction of households that grew cotton was not so high. In 2008/09 and 2009/10, the average rate of adoption was 57.3 percent, with a large standard deviation across villages. In the village with the highest adoption rate, 85.2 percent of households grew cotton, while only 18.8 percent grew cotton in the village with the lowest adoption rate. However, according to a CMDT representative for the Yorosso cercle, the three communes near Simona (specifically, Kifosso, Koury, and Yorosso) all boast villages in which over 95 percent of households grow cotton. The three exceptions are the commune headquarters themselves, where the mayors reside, since these communes have higher populations and more diversified economies. The representative suggested that many households adopt cotton in these cercles because they are

more isolated from the economic activity surrounding Koutiala, so that households have fewer alternative sources of income and poorer access to active coarse grain markets, accessible credit, and affordable fertilizer. Therefore, they are more reliant on the services provided by CMDT.

### *2.2.2 Coarse Grains*

Unlike the highly centralized CMDT, the structure of the coarse grain subsector consists of a wide range of private actors since the liberalization of the cereal market in the early 1980s. Today, the general coarse grain value chain involves various input dealers, creditors, farmers, collectors, wholesalers, semi-wholesalers, retailers, processors, and transportation, and storage service providers (Mali Assessment 2011). Furthermore, whether or not a household decides to sell its coarse grain, there are food processing requirements before consumption. While this work can be done manually within the household, enterprises have sprung up to grind coarse grains into flour, even in rural villages. Maize's value chain differs from millet and sorghum in that it can also be consumed as a fresh crop, can be processed for livestock feed, and has higher input requirements; still, the value chains of maize, millet, and sorghum are similar.<sup>3</sup>

Whereas the cotton industry has struggled, the coarse grain subsector, and especially maize production, has been characterized by steady growth. Indeed, both millet and sorghum production have increased, but maize has recorded the fastest growth of any rain-fed coarse grain cereal in Mali for the past two decades. The share of maize within total cereal production has increased from around 10 percent in 1991 to nearly 18 percent in the late 2000s (Mali Assessment 2011). Increasingly, many subsistence farmers are turning to maize due to its

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<sup>3</sup> Both Boughton (1994b) and Diallo (2011) have studied Mali's maize subsector in great detail and have diagrams illustrating its value chain.

growing market demand and higher yields—each stalk is capable of producing between two and three healthy ears, whereas millet and sorghum only produce one tassel.

However, maize is the riskiest coarse grain to produce with higher input requirements for labor, fertilizer, and rainfall. By comparison, millet and sorghum are better at resisting drought and more suited to arid climates and soil of poor quality. While both millet and sorghum yields increase with fertilizer use, most Malian farmers choose not to apply fertilizer to millet or sorghum, presumably because the perceived marginal return of doing so is less than the marginal cost. However, all three coarse grains are susceptible to pests, such as crop-specific disease or locusts. Understanding coarse grain input requirements and the nutrient-draining nature of cotton also explain crop rotation as taught by CMDT and practiced by many households in Simona and elsewhere. After growing cotton, a typical household would grow maize, which benefits from residual fertilizer applied to the cotton, followed by sorghum and millet. CMDT also teaches that crop rotation can help with weed and pest control.

Whether it is because of risk-adverse behavior or household demand for a diverse diet, it is common for households to produce all three coarse grains. While similar, a few defining traits determine southern Malians' preference for both production and consumption decisions. To start, all three coarse grains are staples to the southern Malian diet as the main ingredient in 'toh', a simple food consumed with sauce for most lunches and dinners. In general, maize toh is considered to taste the best (based on informal polls), although sorghum toh is also tasty and is rich in iron, and the sourer taste of millet is preferred for breakfast porridge. As discussed in Chapter 3, perhaps certain taste preferences also affect production choices.

Table 2.1 shows the adoption rate of these coarse grains by the seven villages in this thesis's dataset, later described in Chapter 5. Data for the first six villages comes from the

Koutiala cercle and was combined between 2008/09 and 2009/10, while the final row displays statistics from Simona in 2010/11. These statistics vary less than the adoption rate for cotton, discussed previously. Of the coarse grains, adoption rates for maize vary the most between villages, falling as low as 65 percent in a village that is very loyal to sorghum and millet. Sorghum is by far the most widely adopted of these coarse grains, with all but four households in the entire sample choosing to grow it. However, all coarse grains are adopted by the majority of households within a village.

**Table 1: Adoption Rates (%) of Coarse Grains by Village**

| <b>Cercle</b>                                              | <b>Commune</b> | <b>Village</b> | <b>Maize</b> | <b>Sorghum</b> | <b>Millet</b> |
|------------------------------------------------------------|----------------|----------------|--------------|----------------|---------------|
| Koutiala                                                   | Fagui          | Nampala II     | 78           | 100            | 94            |
| Koutiala                                                   | Sinkolo        | Tonon          | 83           | 100            | 60            |
| Koutiala                                                   | Sincina        | Kaniko         | 84           | 100            | 100           |
| Koutiala                                                   | Sincina        | Try I          | 65           | 100            | 100           |
| Koutiala                                                   | Koutialaa      | Signe          | 86           | 96             | 92            |
| Koutiala                                                   | Mpessoba       | Gantiesso      | 94           | 96             | 83            |
| Yorosso                                                    | Yorosso        | Simona         | 96           | 100            | 92            |
| <b>Average Adoption Rate:</b>                              |                |                | 84           | 99             | 89            |
| <b>Average Hectares per Household (if Adopted):</b>        |                |                | 1.3          | 3.2            | 2.9           |
| <b>Share of Total Hectares Allocated to Coarse Grains:</b> |                |                | 16%          | 46%            | 38%           |

Encouraged by recent growth, the Malian government has set ambitious goals to increase its country's coarse grain production significantly. Although the goals would have production for all coarse grains increasing in absolute terms, maize's share would increase, moving from 15 percent to 39 percent of total cereal production, while corresponding shares of millet and sorghum would fall from roughly 50 percent to just 33 percent by 2012/13 (Mali Assessment 2011). Thus, with maize emerging as a priority food crop, it will be especially important to examine its relationship to the share of land devoted to cotton and the other coarse grains.

### 2.2.3 Secondary Crops

In addition to cotton and the coarse grains, Malian households may choose to grow a variety of other crops during the rainy season, including peanuts, cowpeas, sweet potato, or other vegetables. While some crops can be grown in cold season when there is less of a labor constraint, the rainy season provides regular watering, an activity that requires much effort in the cold season after the rains stop. Hence, outside of a small vegetable garden, many households in the Koutiala area grow other crops in rainy season. Since this study is mostly concerned with these crops when they compete with cotton and coarse grain production for shares of cultivated land, the discussion will be focused entirely on their production in rainy season.

**Table 2: Adoption Rates (%) of Secondary Crops by Village**

| Cercle                                                       | Commune   | Village    | Secondary Crops | Peanut | Sweet Potato | Cowpea | Rice | Other |
|--------------------------------------------------------------|-----------|------------|-----------------|--------|--------------|--------|------|-------|
| Koutiala                                                     | Fagui     | Nampala II | 90              | 68     | 0            | 56     | 32   | 34    |
| Koutiala                                                     | Sinkolo   | Tonon      | 52              | 27     | 0            | 29     | 13   | 33    |
| Koutiala                                                     | Sincina   | Kaniko     | 84              | 68     | 26           | 62     | 8    | 28    |
| Koutiala                                                     | Sincina   | Try I      | 85              | 71     | 40           | 56     | 0    | 35    |
| Koutiala                                                     | Koutialaa | Signe      | 90              | 74     | 22           | 72     | 6    | 10    |
| Koutiala                                                     | Mpessoba  | Gantiesso  | 98              | 91     | 13           | 57     | 31   | 39    |
| Yorosso                                                      | Yorosso   | Simona     | 66              | 44     | 8            | 24     | 10   | 48    |
| <b>Average Adoption Rate:</b>                                |           |            | 81              | 64     | 15           | 51     | 15   | 33    |
| <b>Average Hectares per Household (if Adopted):</b>          |           |            | 2.1             | 0.8    | 0.5          | 1.3    | 0.9  | 0.8   |
| <b>Share of Total Hectares Allocated to Secondary Crops:</b> |           |            | -               | 37%    | 5%           | 35%    | 8%   | 15%   |

This study will refer to these other crops as the “secondary crops,” not as a judgment of their economic or nutritional value, but due to their “secondary” role in the Koutiala farming system and this study’s focus on cotton and coarse grains. Since all secondary crops will be aggregated for the econometric analysis, Table 2.2 summarizes key information about common secondary crops in the seven villages surveyed in the Koutiala production zone, including adoption rates by village, the average hectares planted per household (if adopted), and the



average share of total secondary crop hectares made up by each individual crop. Data for the first six villages was combined between 2008/09 and 2009/10 as are described later in Chapter 5. The final row displays statistics from Simona in 2010/11.

The adoption rates of various secondary crops vary by village. For example, cowpeas and peanuts are grown by the majority of households in some villages, and the former is typically cultivated on more than one hectare. Rice also has a higher adoption rate in Gantiesso and Nampala II and, where adopted, is grown on almost one hectare. Compared with the Koutiala villages, Simona's adoption rates average a bit lower. Only Simona's "Other" category has higher measures with a 48 percent adoption rate, likely due to increased *jatropha* production on marginal lands, which has been promoted there by entrepreneurs and non-profits alike.

Clearly, the types of crops being clustered together as secondary are diverse and, in some cases, seem to be common household staples, but they also have much in common. At least in Simona, there were a couple ways to identify secondary crops. First, they were often planted on marginal lands and only after the successful planting of the coarse grains. Moreover, these plots were usually planted and maintained by the household's women using manual tools like the hoe or 'daba'. Then, after the harvest, the yields were mainly used for household consumption, as snacks or to supplement meals, though households with excess could sell at market. Rice production is the exception here, as it is labor- and capital-intensive crop like cotton, but its adoption rates are too low to include it as its own outcome category.

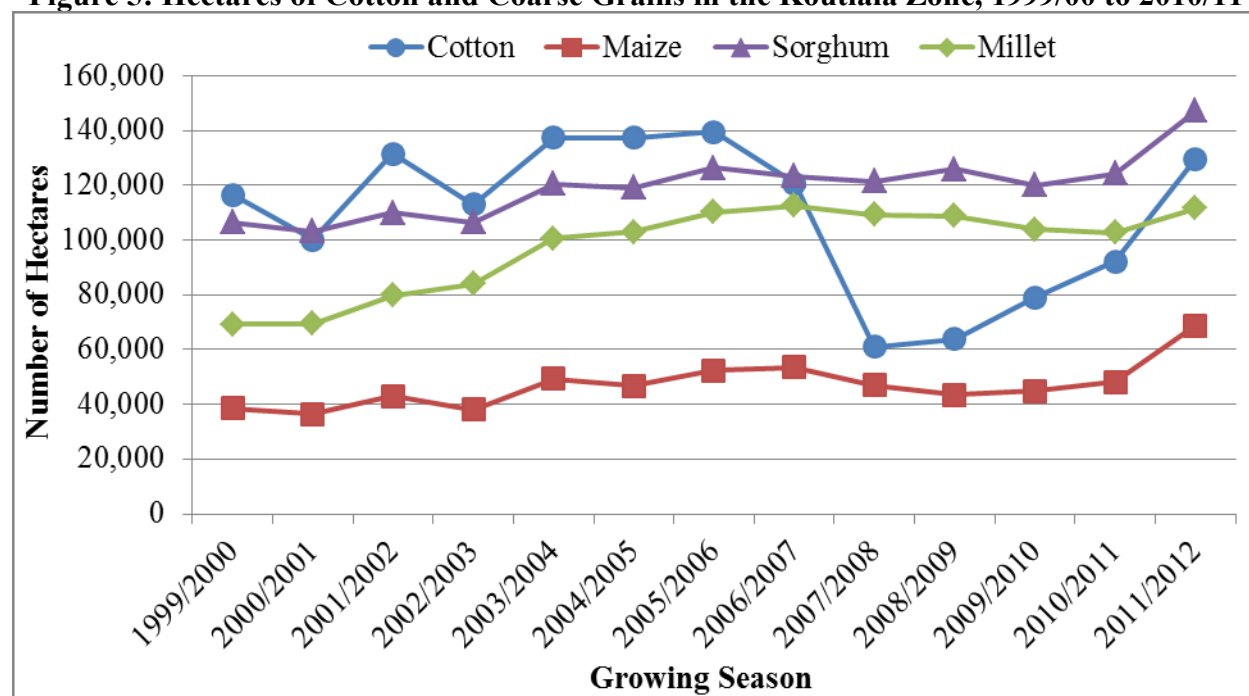
Thus, one may expect that households growing secondary crops share some telling characteristics. Their ability to diversify may be the result of excess labor and human capital (e.g., knowledge of sweet potato farming) as well as aversion to risk. These households may also have an increased preference for these food products, which are often considered luxury goods.

On the other hand, if a farmer devotes a significant share of his land to a secondary crop, he may have recognized his comparative advantage in producing the crop as an income-generating activity. These are patterns that may appear in the analysis of the model.

#### 2.2.4 Conclusion

In this chapter, I have described each subsector and presented some basic descriptive information on the adoption of these crops in the Koutiala production zone. Using the CMDT data, I will finish by comparing aggregate hectares devoted to cotton and coarse grains. Unfortunately, CMDT does not collect data on any secondary crops, but they will be included in the econometric analysis described in later chapters.

**Figure 5: Hectares of Cotton and Coarse Grains in the Koutiala Zone, 1999/00 to 2010/11**



*Source: Author's manipulation of data from CMDT, Koutiala Regional Office*

Figure 5 presents the total cultivated hectares for cotton, maize, sorghum, and millet over the past decade in the Koutiala production zone. Of course, cotton is the most uneven; in two years, it drops from occupying the most land area to aggregate hectares that are below sorghum

and millet, and just above maize. All three coarse grains saw increases in hectares planted, though small declines for millet and maize occurred at the same time as the cotton strike. Ultimately, it appears that millet had the largest growth over the decade in absolute terms, adding over 30,000 hectares. Surprisingly, it does not appear that the decline in cotton was compensated with large increases in hectares allocated to coarse grains, as one might expect due to the freeing up of inputs such as land and labor that would have been previously dedicated to cotton production. But again, this graph does not account for secondary crops and is only a measure of land area, not of yield or production.

However, while these aggregate figures illustrate the effects of the 2007 cotton strike on crop shares, they do not explain what is happening at the household level, which is critical for understanding the farming system in greater detail. The structure and conduct of the subsectors described in this chapter hint at what might influence farmers' planting decisions, but there are many other factors to consider. To determine why households make certain planting decisions, Chapter 3 presents an agricultural household model, a theoretical framework for household decision-making that is the foundation for our analysis.

## **CHAPTER 3: CONCEPTUAL MODEL**

This chapter presents and justifies the theoretical framework for this thesis by discussing its assumptions of human decision-making in the context of Mali's Koutiala production zone, summarized in Chapter 2 and Appendix 1. It begins by discussing the Malian farmer as a rational actor and his household's utility maximization problem. Next, I present an agricultural household model and use it to justify a reduced-form land allocation function that will inform the selection of explanatory variables in Chapter 4.

### **3.1 Malian Farmers as Rational Actors**

In perhaps his most influential work, Theodore Schultz (1964) put forth his “efficient but poor” hypothesis, which rejected that poor farmers were inefficient because of cultural characteristics (e.g., laziness), but rather, asserted that poor farmers make efficient decisions with the few resources to which they have access. Thus, the problem is not the decision-making, but the lack of resources and technology. His theory had significant implications for development policy as it implies that the most effective way to assist these farmers is to introduce and encourage the adoption of new factors of production that increase a farm's productive potential (Ball and Pounder 1996) and the human capital needed to exploit it.

Today, there is still debate as to whether poor farmers are efficient—that is, do they equate marginal returns with marginal costs—but Schultz's work has brought about an implicit paradigm in modern development economics of the “rational but poor” farmer (Duflo 2003). This paradigm implies that the poor farmer should be treated as a rational agent as assumed under the neo-classical economic model, recognizing that both efficiency and rationality may vary given different social and cultural values. Thus, as long as these social and cultural values

are understood along with a given set of economic incentives, the bottom line is that the decisions of poor farmers are logical, and perhaps predictable.

Yet for many years economists did not presume that the rural poor were rational, and it is even a question discussed among Peace Corps Volunteers in Mali. After all, is it logical to buy and brew tea and sugar daily, but not use soap to wash your hands before meals? In Mali, maybe so. Consider that in Mali, household decisions are made by its older men, who derive their value from physical wealth as well as their social status within the community. Especially in small villages, respect is a highly valued commodity that affects the individual and his household. As it is customary to drink three rounds of tea after lunch during the day's hottest hours, brewing tea to share with neighbors and friends is a way to earn and maintain respect in the village, and conversely, refusing even to sit and drink tea is considered rude. However, washing with soap, while cheap, is seen as a hassle, and those Malians who have been educated about its benefits have yet to be convinced of its value in saved health expenditures. An equivalent comparison may be flossing teeth in United States—a healthy habit that most are taught but that far fewer practice regularly, despite what they may tell their dentists. Therefore, if the perceived value of soap is low while the perceived social value of tea is high, and both cost approximately the same, the rational decision is to buy tea and sugar.

Another question commonly asked by Peace Corps Volunteers: how is it rational to buy your family its third motorcycle when all of your children are chronically malnourished? Again, it comes down to the defining the specific value system employed by Malian households. So what gives a third motorcycle value? Economically, it may reduce costs for market transactions requiring transport, especially for larger households of twenty people or more. It may also be a gift or a promised benefit to a hard-working adult male, working either on the farm or away,

which earns him respect and ensures his further contributions to the household. Additionally, it generates respect for the household as a status symbol and can be used to give favors to neighbors and friends in need of transport. Similarly, it further reduces the risk of being stranded in a health-related emergency when quick transport to a regional hospital is dire. Finally, a motorcycle is a method of turning cash into capital, and less cash means reduced social pressure to give aid to struggling neighbors and friends come the next hungry season. By contrast, the perceived value of having nourished children is lower since most families do not even understand that their children are malnourished. The bloated belly on many children due to kwashiorkor, a protein-deficiency, is often seen as a positive sign of a full stomach. Therefore, until Malians understand that their children are malnourished and how this may stunt physical and mental growth, and thus future household productivity, it is rational to purchase a third motorcycle even when a Peace Corps Volunteer thinks that same money should be spent on more vitamin- and protein-filled foodstuffs.

Like many studies in the field of development economics before it, this thesis also assumes that its population, the Malian household, is a rational agent while understanding that they face an entirely different set of market and social incentives that may easily be misunderstood by the researcher. The goal of the researcher then is to properly understand the factors that do influence this rational decision-making. To quote Schultz, “Most people in the world are poor. If we knew the economy of being poor, we would know much of the economics that really matter” (1980).

### **3.2 Malian Household Maximization Problem**

The next matter to settle is what the rational Malian household is attempting to maximize. This question is complicated by the semi-subsistent nature of the Malian household in the

Koutiala production zone since it exhibits the characteristics of both a producer and a consumer. It is heavily engaged in agricultural production and must make decisions concerning the allocation of inputs and outputs, yet it consumes a significant proportion of that production to meet its own household's needs and desires. Whereas the goal of competing producers or firms is to maximize profit by producing to the point where marginal cost is equal to marginal revenue, the goal of an individual consumer is to maximize utility (i.e., the preference for a certain set of goods over another) given a budget constraint (Nicholson and Snyder 2008). As a semi-commercial farm, do Malian households seek to maximize profit, utility, or both?

In the presence of perfect input and output markets (i.e., those free of transaction costs and fully capable of hedging risk), it should be safe to assume that households seek to maximize profit. In this scenario, households would choose the crop or set of crops in which they held particular comparative advantage. Then, they would choose to produce efficiently and maximize profit knowing that they can consume more, and thus attain a higher level of utility, with more profit than with less profit. In other words, if every utility maximization problem is subject to a budget constraint, then the primary objective of the household would be to loosen the budget constraint by increasing their income through profit maximization. This profit level directly affects consumption, but consumption does not affect production decisions. The household model literature labels this concept as separability (Udry 1996).

On the other hand, non-separability occurs when a household's decisions regarding production are affected by its consumer characteristics, such as individual taste preferences and household demographics. This is often true when market failures limit the household's ability to utilize additional profit earned through specialization (de Janvry and Sadoulet 2006). Specifically, a market failure occurs when the cost of a market transaction generates a disutility

greater than its potential utility gain, so that even if the market exists it is still not used for the transaction (de Janvry, Fafchamps and Sadoulet 1991). For example, if a household wants both sorghum and millet, but the cost of finding a vendor and transporting a ton of millet is greater than the additional profit earned by exclusively growing sorghum, then the rational decision is to simply grow both at the desired quantity. In addition to high transaction costs, other market failures concerning risk, credit, labor, and land can also lead to non-separability in the household model. In fact, Udry (1996) uses separability as a benchmark for measuring the extent of market failures in Africa. When combined, these various potential market failures weaken the argument that Malian households seek to maximize profits, because it becomes logical to take household consumption preferences into account.

This makes way for the second solution to the household maximization problem, which supports non-separability. It assumes that semi-commercial farms aim to maximize expected household utility, which is some function of expected utility of each individual in the household. Under this maximization problem, agricultural production can then be incorporated as part of the household's resource constraints. For instance, agricultural production is a large determinant of a household's budget constraint, contributing to consumption or cash generation depending on whether or not crops are sold at market. Since markets are unreliable, most farmers make production decisions based on consumption preferences. These assumptions form the basis for the agricultural household model: a utility-maximizing model subject to budget and other resource constraints.

Other methods have been proposed for explaining the rural household's maximization problem, most of which try to mix profit and utility maximization into a multi-objective approach. Fisk (1962) promoted a subsistence affluence model in which households first devote



resources to meet their own demand and then employ any excess resources toward income generation. In a sense, this splits the agricultural household model into a two-step process, a framework that has proven useful for some studies (Stent and Webb 1975; De Boer and Chandra 1978). Similarly, another study used goal-programming software to maximize five objective functions, four to maximize crop yield for consumption during each season and another to maximize annual net revenue (Lee, Tipton and Leung 1994). Some researchers have even experimented with using responses from goal preference surveys to weigh the importance of various household objective functions, though without finding significant differences between those results and others found assuming profit-maximization (Barnett, Blake and McCarl 1982). These alternative approaches have merit as they represent efforts to better explain farmer decision-making in developing countries, but they may overcomplicate what can be simplified by the agricultural household model.

For this reason, this thesis will develop an extension of the agricultural household model. It elegantly captures the effects of a household's consumption and production decisions and has a more substantial literature that expands upon it, which has been summarized in Appendix 3. Most importantly, its utility-maximizing approach seems more congruent with how Malians seem to talk about agricultural production as a part of their lives. For example, when asked why they hoped to increase production of a particular food crop for next year, farmers from Simona most often responded that it tasted good and their households enjoyed it—very few mentioned that they expected its price to go up. Perhaps because many Malians do not truly believe that they can become rich through hard work on the farm, it is rational that agricultural production is more a means to utility maximization.

### 3.3 Determinants of Crop Choice and Land Allocation

So far, this chapter has argued that Malian farmers are rational and their households' primary objective is to maximize expected utility subject to a set of resource constraints. These assumptions are best represented in the agricultural household model which was popularized by Singh, Squire, and Strauss (1986), but has been greatly expanded upon since.<sup>4</sup> According to Dorward (2011), the main contributions of this model are representing the interactions between consumption and production decisions (i.e., non-separability, as defined above) present in household decision-making among the rural poor and, as a result of later work, identifying the effect of market failures for labor, variable inputs, credit, and staple crops.

By adapting the agricultural household model for farming households in Koutiala, I hope to specify a theoretical model that helps support assumptions made about rural household decision-making in the empirical analysis. Thus, this framework identifies potential determinants of crop shares that will soon establish which variables are included in the econometric analysis. A summary of this agricultural household model used for this process is presented below:

$$\begin{aligned} \text{Max } U &= f(X, Y, H) && \text{utility maximization, s.t.} \\ P_x X + TC_{bx} + P_y Y + TC_{by} &\leq P_x Q - TC_{sx} - P_v V - TC_{by} + \pi_y && \text{budget constraint} \\ Q &= f(F, V, A, K, \sigma) && \text{production constraint} \\ H + F + O &= T && \text{time constraint} \\ X, Y, Q &\geq 0 \end{aligned}$$

As rational agents, poor farmers strive to maximize their expectation of future household utility, which is a function of leisure  $H$ , consumption of agricultural goods  $X$ , and consumption

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<sup>4</sup> Again, see Appendix 3 for a summary of the agricultural household model and some of its extensions.

of other goods  $Y$ . Utility is maximized subject to a budget constraint in which the cost of consumption, determined by prices  $P_x$  and  $P_y$  and transaction costs for buying  $TC_b$ , is less than or equal to profits from other activities  $\pi_y$  and profits from crop production, which is equal to this value of production (output  $Q$  times  $P_x$ ) minus the cost of inputs ( $V$  times  $P_v$ ) and transaction costs for selling  $TC_{sx}$ . Also present is a production constraint, for which output is a function of farm labor  $F$ , other variable inputs  $V$ , land area  $A$ , capital  $K$ , and risk  $\sigma$ . Household choices are further restricted by a time constraint, which limits the sum of farm labor  $F$ , leisure  $H$ , and off-farm labor  $O$  to be less than the household's total time endowment  $T$ . Note that all labor is assumed to come exclusively from the household, and so does not factor into the budget constraint. Finally, we assume that  $X$ ,  $Y$ , and  $Q$  are non-negative values.

The research question asks which factors affect land allocation of standard Malian crops in the country's cotton-growing region. Land allocation of crops is the main determinant of agricultural production, represented by the variable  $Q$ . While other household choices (e.g., fertilizer usage) affect total production, most supply response models use land area as a proxy for total production, since the two are highly correlated and because agricultural production is difficult to measure (Askari and Cummings 1977). Thus, here,  $Q$  will represent a vector of the portfolio of crops chosen and the share of land devoted to those crops.

Within the model, four different types of variables influence the choice of  $Q$ . First, variables that may lead households to specialize in the production of a particular crop include the availability of farm labor  $F$ , other variable inputs  $V$ , land area  $A$ , capital  $K$ , and depending on the crop, price  $P$ . Second, variables that may discourage specialization and lead to diversification include risk  $\sigma$ , transaction costs  $TC$ , and seasonal food constraints. These factors force a household to contemplate the reality of missing markets, and how this might change their

expected utility. These are the competing influences that emerge from the modified budget constraint.

Third, as a result of missing markets, the agricultural household model also predicts that household tastes and preferences will directly affect the crop planting decisions and production. Thus, household-level variables that may affect preferences for food, other consumption goods, and leisure—such as ethnic group and family structure—should also be included. In addition, a household's education may affect its preferences for consuming various goods, while also equipping it to make more efficient production choices. Thus, understanding the individual traits of household members is essential.

Finally, a fourth set of variables exists that serve as alternative ways for the household to earn profit and seek more utility. This group consists of the profits from other activities  $\pi_y$ , though such profits may represent other outcome variables in a model seeking to maximize utility. That is, the decision to engage in other income-generating activities, be it raising livestock or sending a family member to the city, requires an assessment of household inputs and future consumption needs, much like agricultural production. However, if the decision to participate in other income-generating activities is made in conjunction with the choice to grow agricultural products, then they are, by definition, simultaneous outcomes. Recognizing a possible simultaneity bias, I will not represent other income-generating activities in the empirical model. Nevertheless, I recognize it here in the conceptual model as a possible influence on land allocation decisions.

To conclude, according to the agricultural household model, crop choice and land allocation at the time of planting is a function of production factors, the characteristics of local

missing markets, household members, and alternative income-generating activities. Together, these make the following expression:

$$Q = f(P, F, V, A, K, \sigma, TC, Hh, \pi_y) \quad \text{reduced-form land allocation function} \quad (1)$$

In the next chapter, I identify specific variables within the dataset that represent most of the factors in this reduced-form land allocation function.

## CHAPTER 4: EMPIRICAL APPLICATION

Having discussed the agricultural household model, this chapter presents the application of the model to household-level data on agricultural production in Mali. This includes describing the source and characteristics of the data, identifying the dependent and independent variables, and justifying their inclusion in the model.

### 4.1 Data Description

To analyze crop shares at the household level, I will draw on data from a couple of sources. Three hundred observations come from two rounds of surveys in the Koutiala cercle, which gathered information on the same households in both 2008/09 and 2009/10. These 150 households were pulled from 6 villages with about 25 households surveyed per village. Data from the Yorosso cercle, which is similarly (if not more) dependent on cotton, consist of an additional 50 observations from Simona in the 2010/11 farming season.

However, the data from the original study that motivated these three survey rounds will not be used in this thesis. Known as the RuralStruc project, the 2006/07 survey was conducted as part of a World Bank study evaluating the effect of structural adjustment programs on rural economies and production systems from seven countries, four of which—Kenya, Madagascar, Mali, and Senegal—are in Africa. Within Mali, four different cercles were surveyed, each representing a unique production system in Mali.<sup>5</sup> Whereas other cercles were of interest because of their rice or exclusive coarse grain production, Koutiala was selected because it is in

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<sup>5</sup> The original four cercles were Koutiala (cotton zone, Sikasso region), Tominian (coarse grain zone, Segou region), Macina (irrigated rice zone, Segou region), and Diema (Kayes region). However, due to limited resources, the Diema cercle was not included in later surveys helmed by IER and PROMISAM.

the heart of CMDT's cotton zone (Samake 2008). The results from different cercles were then analyzed, compared with each other, and then compared with development indicators from other countries.

Not surprisingly, the RuralStruc survey had various implementation partners, including Mali's Institut d'Economie Rurale (IER), France's Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), and Michigan State University with its Project to Mobilize Food Security Initiatives in Mali (PROMSIAM). Capitalizing on their involvement in the RuralStruc survey, IER and PROMISAM also conducted a second and third round of surveys in 2008/09 and 2009/10, respectively, with funding from USAID and the Bill and Melinda Gates foundation. Where families had not moved or been reorganized, the survey sample consists of those households originally surveyed from the RuralStruc project (Murekezi forthcoming). These are the two surveys whose data is used for our analysis, but again, the RuralStruc data are not used in this study due to some inconsistencies between it and the design and methodology employed by IER and PROMISAM.

The surveys led by IER and PROMISAM were very comprehensive. They asked for detailed information on household demographics and acquired assets, including farming equipment and livestock. Further, the dataset describes the household's agricultural production in full, including land allotment and some other measures not needed for this study, such as production levels and input costs. While the RuralStruc and original Koutiala dataset actually contain households from three cercles, this thesis does not use data for all the households surveyed, but only those from Koutiala.

So how were the villages and households selected for the survey? Again, each cercle was strategically selected to best represent the different agricultural systems in Mali. Similarly, the

selection of the six villages was purposive in order to ensure representation of intra-cercle diversity in a region known for its economic, social, and ecological homogeneity. The criteria for village selection were primarily based on two factors: population and access to markets. The latter criterion simply distinguished whether market access was easy or difficult; three villages are described by each category. Table 3 below, adapted from Samake (2008) Table 81, lists the six villages, their population, ease of market access, average cultivated hectares per household, and the average number of members present in the household.

**Table 3: Description of Six Villages in Sample from Koutiala Cercle**

| <b>Village</b> | <b>Commune</b> | <b>Pop. 1998</b> | <b>Market Access</b> | <b>Avg. Cultivated Hectares per Household</b> | <b>Avg. Size of Household</b> |
|----------------|----------------|------------------|----------------------|-----------------------------------------------|-------------------------------|
| Nampala II     | Fagui          | 982              | Difficult            | 10.6                                          | 14.9                          |
| Tonon          | Sinkolo        | 286              | Difficult            | 7.6                                           | 14.1                          |
| Kaniko         | Sincina        | 1735             | Easy                 | 10.9                                          | 20.2                          |
| Try I          | Sincina        | 864              | Easy                 | 8.5                                           | 16.1                          |
| Signe          | Koutialaa      | 1005             | Easy                 | 9.9                                           | 18.3                          |
| Gantiesso      | Mpessoba       | 3219             | Difficult            | 10.7                                          | 18.5                          |

The RuralStruc report states that often households differ more within villages than between villages, on average. For this reason, households within the six villages were chosen at random to best capture this variation. Twenty-five households were surveyed in five villages, and twenty-eight in the sixth, but after data cleaning, this portion of the sample consists of 153 households (Murekezi 2011). However, because we have two observations for each household, this doubles our sample size and means that each village is represented by nearly 50 observations. Because outcomes are likely to be highly correlated over time within the same household, I am careful to control statistically for potential correlation in the econometric model presented in Chapter 5.

Having lived east of the Koutiala cercle for two years as a Peace Corps Volunteer, I thought it was important to include at least one village from the Yorosso cercle in the dataset; the



area relies heavily on cotton, is similar climatically, but is generally more isolated. Therefore, I implemented a survey in Simona for the production year 2010/11. Based on the PROMISAM survey used in the Koutitala cercle, households were asked a range of questions concerning their family's demographics, livestock and capital assets, field allocation, crop production, input procurement, market participation, and plans for the following year. Out of Simona's 140 households, 50 were randomly selected to participate; only one abstained, which I replaced with a randomly-selected substitute household. This allows Simona to be fairly represented as a village in the dataset, bringing the total number of observations up to 350. Compared to the other villages in Table 4.1, Simona has an approximate population of 2,500, difficult market access, an average of 11.6 cultivated hectares per household, and an average household size of 18.9 people.

Due to the amount of work required and the village's preference for speaking Minianka, literate locals were trained as enumerators to carry out the survey under my supervision. Admittedly, given their lack of experience, this was a possible source of human error. Thus, upon receiving each survey, I reviewed it privately with the enumerator, discussed any errors or inconsistencies, and required him to return to the households if necessary. Additionally, the survey was re-designed specifically for Simona in order to best address relevant research questions and to assist the enumerators. For example, surveys had to be translated into Bambara and some terminology had to be revised, such as concepts of "units" and "individual property." This reworking was only possible after attaining a cultural understanding of the village thanks to many informal interviews with Simona farmers.

One main limitation of the Koutiala and Simona data is their susceptibility to human error. All estimates of hectares planted as well as total production are based on household memory. Thus, efforts were made by IER to include multiple household members, men and

women, during the survey interview to encourage collaboration and, hopefully, more reliable estimates. For Simona, efforts were also taken to survey groups of farmers within each household, instead of just the household head, who is sometimes removed from current farming activity due to old age. Additionally, all survey rounds were conducted between February and May of the production cycle, at least three to four months after harvest and nine months since planting. While any delay in survey questioning raises the probability of human error, surveys were implemented during these months because they are Mali's inactive, hot season. Since planting typically begins in May and the harvest usually ends in November, this was the optimal time to interview a large number of households.

## 4.2 Dependent Variables

For any empirical application, the selection of variables must be informed by a conceptual model. At the end of Chapter 3, it was argued that the agricultural household model is a fair representation of how households in the Koutiala production zone make decisions regarding crop choice and land allocation. Thus, equation (1) is repeated here as equation (2):

$$Q = f(P, F, V, A, K, \sigma, TC, Hh, \pi_y) \quad \text{reduced-form land allocation function} \quad (2)$$

Again, it states that land allocation  $Q$  is a function of expected prices  $P$ , the availability of family labor  $F$ , other variable inputs  $V$ , land area  $A$ , owned equipment (or capital)  $K$ , risk  $\sigma$ , transaction costs  $TC$ , household characteristics  $Hh$ , and finally other sources of household income  $\pi_y$ . The challenge is now selecting data measured in the Koutiala and Simona survey rounds that best represent these variables.

Starting with the left-side of equation (2),  $Q$  is the dependent variable, representing a vector of crop shares for the portfolio of crops chosen by a household. As discussed in Chapter 2, the portfolio of crops for the Koutiala production zone consists primarily of cotton, maize,

sorghum, and millet. Households may also cultivate peanuts, beans, or other crops, all of which are grouped together under the category of secondary crops. The shares of a household's total cultivated hectares devoted to each of these crops are represented by *CottonShare*, *MaizeShare*, *SorghumShare*, *MilletShare*, and *SecondaryShare*, respectively. This gives us five dependent variables—the percentage of total cultivated land devoted to cotton, maize, sorghum, millet, and secondary crops—the sum of which represents all cultivated land on a farm.

**Table 4: Summary Statistics for Dependent Variables**

| <b>Variable</b> | <b>Mean</b> | <b>Std. Dev.</b> | <b>% 0 Share</b> | <b>Minimum<br/>(after 0)</b> | <b>Maximum</b> |
|-----------------|-------------|------------------|------------------|------------------------------|----------------|
| CottonShare     | .1354       | .1243            | .3714            | .0561                        | .4615          |
| MaizeShare      | .1046       | .0791            | .1600            | .0217                        | .6000          |
| SorghumShare    | .3488       | .1774            | .0114            | .0313                        | 1.000          |
| MilletShare     | .2401       | .1607            | .1143            | .0435                        | .9231          |
| SecondaryShare  | .1712       | .1512            | .1886            | .0014                        | .6957          |

Table 4 summarizes some basic descriptive information about these five dependent variables, including mean, standard deviation, percentage of observations with zero share (meaning they did not grow the crop at all), minimum shares (after zero), and maximum shares. The standard deviations in Table 4 are revealing as they represent the variance in their respected crop shares across households, a sufficient amount of which is necessary to produce significant results in the econometric analysis. The standard deviations also show that crop shares definitely vary between households.

Another important detail revealed in Table 4 is that while every crop has some observations report a zero share, a significant portion of households are not growing cotton. In fact, only about 63% of observations grew any cotton at all. Therefore, more so than with the

other crops, results that suggest a decrease in the expected share of cotton due to a change in the explanatory variable may explain either a marginal decrease in the share of land devoted to cotton or, perhaps for some households, dropping cotton altogether. This will also be an important detail for interpreting the results.

### **4.3 Independent Variables**

Continuing with the right side of equation (2), variables present in the dataset were selected to represent the explanatory factors for crop shares as informed by the reduced-form land allocation function and the agricultural household model. On the next page, Table 5 displays these variables with a brief description. After, further explanation is also provided for each factor represented in equation (2), including whether or not it is represented in the model and why.

**Table 5: Summary of Independent Variables**

|                                                                     | Variable                       | Description                                        | Mean | Std Dev |
|---------------------------------------------------------------------|--------------------------------|----------------------------------------------------|------|---------|
| <b>LABOR AND LAND: Household Members per Hectare and Inactivity</b> |                                |                                                    |      |         |
| 1                                                                   | MenPerHct                      | # of adult males (age $\geq 15$ ) per hectare      | 0.42 | 0.23    |
| 2                                                                   | WomenPerHct                    | # of adult females (age $\geq 15$ ) per hectare    | 0.50 | 0.30    |
| 3                                                                   | YouthPerHct                    | # of children (6 $\leq$ age $\leq$ 14) per hectare | 0.57 | 0.59    |
| 4                                                                   | InfantsPerHct                  | # of children (age $\leq 5$ ) per hectare          | 0.33 | 0.32    |
| 5                                                                   | WomenPerHct*<br>InfantsPerHct  | Interaction term between (2) and (4)               | 0.22 | 0.57    |
| 6                                                                   | %MenInactive                   | % of adult males who are inactive                  | 0.05 | 0.13    |
| 7                                                                   | MenPerHct*<br>%MenInactive     | Interaction term between (1) and (10)              | 0.02 | 0.06    |
| 8                                                                   | %WomenInactive                 | % of adult females who are inactive                | 0.12 | 0.17    |
| 9                                                                   | WomenPerHct*<br>%WomenInactive | Interaction term between (2) and (12)              | 0.06 | 0.09    |
| <b>CAPITAL: Farming Equipment</b>                                   |                                |                                                    |      |         |
| 10                                                                  | Sprayers                       | # of sprayers owned                                | 1.17 | 0.87    |
| 11                                                                  | Plows                          | # of plows owned                                   | 1.75 | 1.86    |
| 12                                                                  | Oxen                           | # of draft oxen owned                              | 2.95 | 2.72    |
| 13                                                                  | Plows*Oxen                     | Interaction term between (15) and (16)             | 7.35 | 17.87   |
| <b>TRANSACTION COSTS: Modes of Transportation</b>                   |                                |                                                    |      |         |
| 14                                                                  | Motorcycles                    | # of motorcycles owned                             | 0.63 | 0.79    |
| 15                                                                  | Bicycles                       | # of bikes owned                                   | 2.11 | 1.49    |
| 16                                                                  | Carts                          | # of draft animal carts owned                      | 0.99 | 0.54    |
| <b>HOUSEHOLD CHARACTERISTICS: Literacy and Ethnic Identity</b>      |                                |                                                    |      |         |
| 22                                                                  | %MenLiterate                   | % of adult males who are literate                  | 0.64 | 0.40    |
| 23                                                                  | MenPerHct*<br>%MenLiterate     | Interaction term between (1) and (6)               | 0.27 | 0.25    |
| 24                                                                  | %WomenLiterate                 | % of adult females who are literate                | 0.50 | 0.45    |
| 25                                                                  | WomenPerHct*<br>%WomenLiterate | Interaction term between (2) and (8)               | 0.26 | 0.32    |
| 26                                                                  | Bambara                        | Dummy: 1 if Bambara ethnicity, 0 if not            | 0.13 | 0.34    |
| 27                                                                  | Senoufo                        | Dummy: 1 if Senoufo ethnicity, 0 if not            | 0.09 | 0.28    |
| 28                                                                  | Peulh                          | Dummy: 1 if Peulh ethnicity, 0 if not              | 0.06 | 0.23    |
| 29                                                                  | OtherEthnic                    | Dummy: 1 if other ethnicity, 0 if not              | 0.03 | 0.18    |
| <b>TIME AND LOCATION: Year and Village</b>                          |                                |                                                    |      |         |
| 30                                                                  | Year_2010                      | Dummy: 1 if from year 2009/10, 0 if not            | 0.43 | 0.50    |
| 31                                                                  | Village_Tonon                  | Dummy: 1 if from Tonon, 0 if not                   | 0.14 | 0.34    |
| 32                                                                  | Village_Kaniko                 | Dummy: 1 if from Kaniko, 0 if not                  | 0.14 | 0.35    |
| 33                                                                  | Village_TryI                   | Dummy: 1 if from Try I, 0 if not                   | 0.14 | 0.34    |
| 34                                                                  | Village_Signe                  | Dummy: 1 if from Signe, 0 if not                   | 0.14 | 0.35    |
| 35                                                                  | Village_Gantiesso              | Dummy: 1 if from Gantiesso, 0 if not               | 0.15 | 0.36    |
| 36                                                                  | Village_Simona                 | Dummy: 1 if from Simona and 2010/11, 0 if not      | 0.14 | 0.35    |

#### *4.3.1 Labor and Land: Household Members per Hectare and Inactivity*

Labor for crop production and food preparation is a key production factor that may also explain land allocation decisions. In the Koutiala and Simona surveys, family labor was measured for each individual by asking whether they typically farmed in the mornings, afternoon, or all day. However, this information cannot represent a household's labor input in a land allocation model. Firstly, while this method measures labor input on a given day, it ignores that labor demands change seasonally, as planting and harvest times often require the most labor. It is not uncommon to see the entire household—at least ages eight and up—helping to pick cotton all day for the few dry days when the cotton boll is mature. However, even if this is the only time a woman works all day, the household head may indicate that she is a full-time farmer, because she is when she needs to be. Accurate measures of degrees of household labor must include a seasonal component to capture the labor demands of planting, weeding, applying variable inputs, and the harvest. Yet even if this more detailed data were available, it would be best for a model trying to predict crop production, but might have still generated skewed results since labor allocation decisions can be endogenous to decisions regarding land allocation and crop choice. For these reasons, these data are not used to estimate family labor in this study.

Rather, we will represent family labor with household size, which in Mali's Koutiala production zone, is assumed to be the household's available supply of labor for farming or other activities. Additionally, a household's size largely defines its consumption needs. However, since our focus is on production potential and consumption demands, a simple headcount to calculate household population is not an accurate representation, as it measures infants on par with adult males. One option then is to calculate an adult equivalence measure that assigns weights to the headcounts of different age and gender categories based on each category's

expected labor input and food consumption. However, one weight could not accurately adjust for both—for example, an infant eats something, but contributes nothing to production—and an estimation's dependence on weights is never ideal when a better option is available. Thus, the model starts by including multiple variables for each relevant age and gender categories: adult men, adult women, youth (ages 6-14), and infants (ages 0-5).

It is also important to consider the supply of land available to the household to cultivate. In this study, the household's number of total cultivated hectares is the measure for household land area. It is the sum of the hectares devoted to each crop that is used to calculate the shares for the dependent variable. However, for over two-thirds of households, the sum of cultivated hectares is not the total number of hectares that the household possesses. The difference is comprised of land rented to other households, newly created farm land not yet ready for cultivation, fallow land that is set aside to regain fertility, and unused arable land.

By choosing total cultivated hectares as the measure of available farm land, I assume that this final category—unused arable land—is non-existent or at most trivial. It is my opinion that if a household possesses land that is suitable for farming, it will cultivate something there, even though a common environmental concern is that households continue to cultivate land that needs to rest every few years. This is the same assumption made by the survey instrument, which collected data on hectares of fallow, rented, and newly created land, but left no room to record hectares of unused arable land. Thus, the sum of cultivated hectares, and not total hectares, is the measure used to represent a household's supply of farm land.

Now, one might expect that if crop production is largely used for household consumption, then land area must be looked at in terms of how many mouths it can feed. In other words, the effect of land area on crop share decisions depends on how many people are working

and eating off that land. For example, I expect households with a higher rate of people per cultivated hectares to produce more maize, which yields more calories per hectare than sorghum or millet. Therefore, the four variables representing headcounts of adult men, adult women, youth, and infants are calculated on a per-hectare basis. *MenPerHct* and *WomenPerHct* measure males and females, respectively, ages 15 and up per hectare, *YouthPerHct* measures children between ages 6 and 14 per hectare, and *InfantsPerHct* measure children between ages 0 and 5 per hectare. Together, these four variables represent a household's labor supply and consumption demand relative to the household's available supply of land. I have also inserted an interaction term between *WomenPerHct* and *InfantsPerHct* to control for an expected negative effect of children ages five and under on their mother's (or other caregiver's) labor productivity. While Malian women are fond of slinging their babies to their back while working, a high number of young children relative to potential female adult caregivers sharply changes the composition and potential labor supply of the household, and thus may affect crop choice and land allocation.

Another related factor that may affect crop choice is what percentage of adult men and women are inactive. An adult may be inactive because he is elderly, severely or chronically ill, disabled, or for some women, in the final stages of pregnancy. In these situations, the individual often has similar consumption needs as other adults in the household, but is limited in their ability to contribute to farm labor. To consider these cases, the variables *%MenInactive* and *%WomenInactive* are included to measure the percentage of household adult men and women, respectively, which were considered by the household to be "inactive" during the farming season. Interaction terms between these variables and *MenPerHct* and *WomenPerHct*, respectively, are also added to the model to capture how the relationship changes across households of varying size. It is important to note that while these individuals may contribute



little or none to farm labor, this rarely means that they do not work in any capacity. Often inactive women will care for young children and assist with food preparation, while inactive men may take up some other income-generating activity (e.g., in Simona, elderly men seemed to prefer rope-making while socializing with friends). Yet these contributions are normally small, and so land allocation decisions must consider inactive family members.

Finally, as there can be many types of farm labor, the characteristics of the land possessed by the household—such as its elevation, soil type, position in the water table, and nutrient availability—can vary greatly as well. Unfortunately, data were not collected on these attributes. However, these land characteristics are somewhat controlled for with the village dummy variables discussed further below, though admittedly, such characteristics can often vary even within the same village. This may be an important consideration in future studies.

#### 4.3.2 *Capital: Farming Equipment*

For rural farmers in Mali's Koutiala production zone, capital accumulation is basically the attainment of farming equipment that can improve agricultural production. Examples range from motorized tractors to 'dabas', a hand-held tool that breaks up earth like a hoe. However, no farmer in the sample has a tractor and every household (I assume) has a daba. The key is to identify capital that is used by enough households to generate reliable estimates, but still varies between households.

The variables *Sprayers* and *Plows* represent the number of sprayers and draft plows, respectively, owned by the household. Similarly, the variable *Oxen* represents the number of bulls or oxen the family owns to pull the draft plow or other draft-powered equipment. The alternative to selecting a few choice types of capital is to calculate an all-inclusive equipment index, but this would require subjective weighting that may ignore how the possession of crop-

specific technology encourages its production. For example, sprayers are used for pesticide application, which is mostly practiced on cotton production. Thus, one might expect that owning high number of sprayers would help convince a household that they can handle growing a larger share of cotton. Finally, an interaction term is included between *Plows* and *Oxen*, because I expect to see a high correlation between the number of draft animals and draft-powered plows owned by the household. After all, each is only functional if it has the other.

By including capital in the model, there is a risk of simultaneity bias; that is, maybe a household owns many sprayers because of other factors that lead the household to prefer cotton production. Sprayers do not lead to more cotton, but cotton leads to more sprayers. I justify this possible inconsistency by looking at the time-frame in which crop decisions are made. As part of a long-term plan to increase cotton shares, a household may plan on investing in additional sprayers, plows, and draft animals over many years. However, at the start of planting, the share of land devoted to cotton is not decided by the household's long-term goals, but by their current capital constraints (among other things), especially since it is unlikely that a household has excess cash or credit during this season to purchase more equipment. Since this study does not examine crop shares over a long stretch of time, we will assume that a household's existing capital is a determining factor of its yearly crop share decisions, and not vice versa.

#### *4.3.3 Transaction Costs: Modes of Transportation*

As discussed in Chapter 3, transactions costs—those associated with the transport and exchange of market goods—have been modeled as a main contributor to market failures. Transportation costs incurred by a market vendor, or the long walk to market for a household buyer, may raise the price of a product enough to prevent an exchange from being mutually beneficial. However, estimating transaction costs per household is very difficult. Not only is it

about distance to and food availability at nearby markets, which can greatly vary even within one spread-out village, but also consists of relationships between household members and market vendors and the ability to transport crops or travel long distances. I will incorporate some variables here to represent transaction costs as best as possible with the available data.

First, specific village-level dummy variables represent ease of market access, as described in the RuralStruc classification of the sampled villages, shown above in Table 4.1. It states that observations identified by the variables *Village\_Kaniko*, *Village\_TryI*, or *Village\_Signe* have “easy” access to a market. While the RuralStruc report does not explicitly reveal how these labels were assigned, a rough spatial mapping of the villages reveals that relative distance to the city of Koutiala was probably the test. The three villages defined as “easy” are approximately twenty kilometers or less from Koutiala, which could be traveled back and forth by donkey cart on market day if need be. However, while Koutiala is the primary market town for both Koutiala and Yorosso cercles, this does not mean that it is the only available market; in fact, even Simona had its own market. Thus, while all villages likely have access to a market, the villages of Kaniko, Try I, and Signe are within walking distance of a large market town that exchanges a far greater range of goods and services. Since most goods in the smaller markets probably went through Koutiala or a similar large town (e.g., Sikasso), access to trade in Koutiala likely reduces transactions costs for market vendors.

Access to private transportation can also reduce transactions costs incurred by a household. To start, the variables *Motorcycles* and *Bicycles* are equal to all of the motorcycles and pedal bicycles, respectively, that are owned by a household (no household in the sample owned a car or truck). Though capable of carrying a small load, these vehicles are primarily for transportation of people. However, both can reduce transportation costs between locations, and

greater mobility can improve other transaction costs as it allows a household to better maintain relationships across distances. For example, many farmers in Simona made a point to travel to a larger market in the cercle at least once a month in order to greet family, friends, and vendors that they knew. Among other reasons, these farmers understood that failure to greet on a regular basis could quickly lead to a breakdown in the relationship. Therefore, one might expect that households with greater transportation capabilities travel to regional markets more often, and thus will face fewer other transaction costs when trading crops at market.

Next, the variable *Carts*, which counts the number of carts owned by a household, assists in transporting large amounts of goods into or away from the city or nearest market. Additionally, carts can be a production factor, as they also help households transport cotton and coarse grains to storage after the harvest. An assumption made here is that each cart is accompanied by a draft animal that is probably a donkey, but possibly a horse or mule. Between the village dummies and variables for household ownership of motorcycles, bicycles, and carts, the model controls for potential differences in transaction costs in the best way the data allow.

#### *4.3.4 Household Characteristics: Literacy and Ethnic Identity*

The first step in characterizing a household is to define its size and composition; this was done in the series of variables that describe a household's labor supply and consumption demand per hectare. After that, other important household traits to consider are the education levels of its adult men and women as well as the ethnic group to which the family identifies. As discussed in Chapter 3, the rationale behind the agricultural household model is that because many households consume their own production, one should expect that variables representing differences in preferences have a significant impact on crop share decision-making.

Starting with education, the variables *%MenLiterate* and *%WomenLiterate* are defined by the percentage of the household's adult men and women, respectively, who are described as literate by the household. These variables are also included as interactions with *MenPerHct* and *WomenPerHct*, respectively, to account for changes in the impact that adults can have on farming decisions depending on the size of household. This set of four variables incorporates literacy as an explanatory factor in the model. Directly, literacy can simplify trade and reduce transaction costs, which may cause a highly literate household to grow more of a marketable crop. Literacy also serves as a proxy for other factors that are difficult to measure, such as intelligence and personal motivation—characteristics that increase the likelihood of completing literacy education and may affect crop share decisions over the long-term. Moreover, literacy may affect individual preferences if the literacy class was accompanied with nutrition education, as is often the case. It will be important to recall what explanatory factors these variables are capturing when interpreting the results.

Notice that in this empirical model, the educational level of the household head is not considered by itself, as is common in many development studies. The reasoning for this is two-fold. First, as discussed in Appendix 1, I assert that while household decisions are authorized or approved by the household head, most adult males participate in the decision-making process depending on the respect and authority granted to them by the family. The eldest brother or elderly father will consider the input of other married men and may grant special weight to their opinions if they are the hardest working (motivation) or wisest (intelligence). Secondly, the intelligence and motivation of a household head is often seen in the percentage of his household members who are educated, even if he is not formally educated himself. One case comes to mind of a respected elder with nearly a dozen sons, all of whom had received some formal education

and most of whom were literate. It is likely that some of the motivation behind the sons' studies was the result of their father's motivation and intelligence, though the elder himself was illiterate and too old (and proud) to really benefit from taking a class. If a variable were to measure household intelligence and drive by only acknowledging his personal educational background, and not that of his family's, it would have failed to capture his own wisdom.

Additionally, variables that measure adult female literacy, and by extension her intelligence and motivation, are also included in the model. While women are not very influential in the patriarchal decision-making process, household leadership will often allow one or more women to produce crops on their own, especially some of the secondary crops which require less equipment to cultivate. Opportunities to do so may be through a garden managed by the village women's cooperative or a smaller parcel of land devoted to the production of beans or peanuts. While such instances may be the result of very deliberate plans by household leadership to maximize labor supply, it often is accompanied—if not entirely motivated—by the household women, either by a desire to generate income or provide a more diverse or nutritious diet for their family. However, these efforts are often perceived as inferior farming and must be in addition to household activities and fieldwork on primary crops during peak labor demands.

Specifically, literacy training can be expected to encourage women's agricultural production in a few ways. First, being literate may assist with market trade or cooperative participation, making it more profitable to cultivate other crops. Secondly, the confidence gained by a woman after having acquired a skill that many men lack may also motivate her to pursue interests in farming or gardening. Furthermore, training received on nutrition and gender empowerment, which usually accompanies literacy programs and classroom studies, may encourage crop production and change her preferences toward more nutritious foods. And as

stated before, literacy also serves as a proxy for inherent intelligence and drive; one may expect that gifted and motivated women are more likely to seek and complete literacy training as well as make additional contributions to household agricultural production.

Next, a series of binary dummy variables representing ethnic groups are incorporated into the model. Since the vast majority of households in the Koutiala production zone identify themselves as Minianka, this ethnic group will be the omitted category to which other ethnic groups are compared. The variables *Bambara*, *Senoufo*, *Peulh*, and *OtherEthnic* represent alternative ethnic identities, and the estimated coefficients on these variables will represent the changes in crop shares associated with each ethnic group relative to the Minianka group. Since each are a binary variable (=1 if part of the ethnic group; =0 if not), the means presented in Table 5, when multiplied by 100, are the percentage of the sample that identify with that ethnic group. The variable *OtherEthnic* is comprised of five ethnic groups, the Soninke and Malinke people from the west and the Bozo, Bobo, and Dogon from north-eastern Mali. Together, they total only twelve households, which is why they are grouped together into one variable, despite the fact that they represent very diverse cultures. For example, most Bozo reside along the Niger River and rely heavily on fishing for their food and livelihood, which is a unique identity for an ethnic group in a landlocked country.

The purpose of dummy variables for ethnic identity is that it may hint at each household's tastes and preferences. If the theory behind the agricultural household model is correct, then in the presence of transaction costs or other barriers to market transactions, a household's tastes and preferences may factor directly into its production choices, including for crop shares. While an ideal analysis might gather information on household food preferences directly or weight each individual's food preferences according to household seniority, this

subjective information would be difficult to collect and interpret. In its place, ethnic identity can explain some of the differences in tastes and preferences across households as certain groups prefer traditional crops and meals, particularly those households migrating from distant regions. For example, those from the north may be less familiar with how to grow and prepare maize, preferring to focus on millet, sorghum, or fonio instead. Of course, this assumes that recent immigrants to new areas still retain many of the traditions and preferences of their home regions. Cotton shares may even be associated with ethnic group as the Minianka and Senoufo peoples, originating from Koutiala's Old Cotton Basin, may have retained cultural knowledge regarding its production as well as perceive the cash crop as linked to their ethnic identity.

One concern is that some of the ethnic identities are highly correlated with certain villages. For example, 60.0 percent of the *Peulh* observations are in one village, 73.9 percent of the *Bambara* are in another, and finally, 93.3 percent of *Senoufo* are in yet another. For this and other reasons, village-level dummies are also included in the model to control for differences in geographic location across the sample.

#### 4.3.5 *Expected Price*

If supply response models have taught anything, it is that farmers respond to expected price changes. However, spanning merely three years, only two of which cover the same households, the data do not support empirical estimates of how price could affect crop shares, even if the data were used as a two-year panel dataset. Rather, the differences in expected price will be captured by dummy variables representing the time and location from where and when the observations originate. This approach assumes that households from the same village and in the same year have very similar price expectations. Given that price expectations and land



allocation strategies are a common topic of discussion among adult men in the dry seasons before planting, this assumption—while not true in every case—is practical.

Specifically, the time dummy variables will represent differences between the 2008/09, 2009/10, and 2010/11 growing seasons and expected changes in price that may have occurred due to unique weather patterns for each of those years. Additionally, the presence of village dummy variables will control for geographic differences in the expected price of coarse grains, including those that may result from foreseen transaction and transportation costs, which were already discussed. However, there is no need to control for geographic differences in the expected price of cotton, since, as stated in Chapter 2, CMDT is mandated to set a pan-territorial producer price for cotton before each planting season.

Finally, the variable *Village\_Simona* identifies the fifty observations from the village in which I served as a Peace Corps Volunteer, which lies east of the other six villages in the Yorosso cercle. These data also represent land allocation at least a year later than the others, during the 2010/11 farming season. Therefore, the *Village\_Simona* dummy variable represents an expected price change through both a time and location difference.

#### 4.3.6 *Determinants Not Included*

Mostly due to a lack of sufficient data and possible simultaneity biases, some of the determinants shown in equation (2), the reduced-form land allocation function, are not represented in the model. These are profits generated by off-farm employment ( $\pi_y$ ), variable inputs ( $V$ ), and a household's risk preference ( $\sigma$ ). This final subsection of Chapter 4 explains the justification for the exclusion of these variables.

The first determinant category not included in the model or Table 5 is profits generated by off-farm employment. Originally, this was partially represented in the model by several

variables equal to a household's number of cattle, sheep, goats, hogs, and poultry. However, it was determined that animal-raising is too closely interrelated to crop production as part of the farming system, thus leading to a simultaneity bias that also does little to explain the effects of off-farm work on crop shares. Ideally, off-farm employment would also include profits gained (or lost) from migratory household members, many of whom go to larger cities such as Koutiala or the capital Bamako to find work or study. Additionally, off-farm income can come from work as a service provider in a village, such as a mechanic, carpenter, shopkeeper, or blacksmith. Unfortunately, in either case, adequate data were not collected in the surveys to provide a reliable estimate of profits earned (or lost) from these activities. Yet, based on my observation, in-village service providers are the least available during rainy seasons since farming becomes their top priority. In Simona, every single household participated in agricultural production, including the top blacksmith, village chief, imam, and pastor, and this is not unique for small villages. Yet while agricultural production may be important for all households in remote communities, it will remain unclear in the analysis how crop shares may be affected by these alternative income sources.

Next, variable inputs are the second determinant in equation (2) that is not represented in Table 5. Originally, it was included in the model since most households order their fertilizer from CMDT long before planting and because knowledge of planned fertilizer application can affect crop shares. For example, a farmer can produce the same maize on his field as his neighbors do if he plants less but uses more fertilizer. However, even though data pertaining to fertilizer type, purchase method, and quantity applied is available, a variable to represent inputs is ultimately excluded due to issues of simultaneity. First of all, it is unrealistic to assume that fertilizer procurement always comes before planting decisions for coarse grains. Households can

decide after planting to apply more or less fertilizer than anticipated due to unexpected changes in weather. Other households may even wait and purchase fertilizer from a market vendor. Secondly, because fertilizer is a requirement for successful cotton production, it must be considered a simultaneous decision. In other words, if you grow cotton, you will use fertilizer; the two decisions go together. This high correlation between fertilizer and cotton hectares also makes fertilizer an unfair estimator of coarse grain shares; households without fertilizer grow no cotton and have higher shares of coarse grains, while those with fertilizer also grow cotton and thus have lower shares of coarse grains. Other options might include finding proxies to represent the price or availability of fertilizer, but government subsidies and the ability of households to procure through CMDT (discussed in Chapter 2 and Appendix 2) mean that these measures are identical across most, if not all, households in the sample. Therefore, representation of variable inputs such as chemical fertilizers is left out of the model.

Finally, a household's risk preference is the other category present in equation (2) not represented in Table 5. Here, risk does not refer to the vulnerability of a household to certain shocks, but rather the household's preference for accepting or averting risk and how this attitude affect their land allocation decisions. However, while understanding a household's risk preference may explain much of their decision-making, it is not included in the model for two reasons. First, risk aversion preference is terribly difficult to measure or proxy at the household level, especially because it is perceived differently by each individual—their estimated probabilities that given events will occur (e.g., weather) as well as aversion behavior. Then of course, this must be weighted to calculate risk aversion at the household level. Secondly, risk preference is tricky to represent in an econometric model because it is difficult to truly separate from every other independent variable. Risk preference are an engrained part of the decision-

making process, and therefore are embedded in other variables. For example, choosing to own a motorcycle or expand a field require an assessment of risk. Since these variables are among the explanatory variables, they can also represent a household's risk preference indirectly. Similarly, there is no explicit measure of household wealth, but measures of the total cultivated hectares and ownership of farming equipment reflect household wealth indirectly. As with wealth, a general representation or proxy for risk aversion preference is another variable that ought to be included, but is not due to a lack of such a proxy in the data.

## **CHAPTER 5: ECONOMETRIC MODEL AND RESULTS**

This chapter begins with a description of the fractional multinomial logit model—the econometric technique necessary to estimate the effect of the explanatory variables on the shares of multiple crops simultaneously. It then presents the results in the form of average marginal effects. Later sections discuss the results for specified categories of related explanatory variables, consistent with classification used in Chapter 4. The chapter ends with an application of the estimated average marginal effects to two example scenarios that characterize a smaller, disadvantaged household and a larger, better-equipped household.

### **5.1 Fractional Multinomial Logit Model**

As its name suggests, the estimation technique used in this paper combines two variations on the standard logit model: the fractional logit and the multinomial logit, all three of which are summarized in Appendix 4. The outcome (i.e., the fractional multinomial logit) is that the explained variable  $y$  is able to represent the different shares of various types of  $y$ , all of which sum to one, much like the various categories in a pie chart. For this reason, the model is in the family of multivariate fractional logit models (e.g., Mullahy 2011; Murteira and Ramalho 2012), because it is measuring the changes in shares of multiple variables simultaneously as a result of some explanatory variables. In other words, it allows one to ask how the slices of a pie chart change between observations as a result of differences in a certain set of related factors. In this case, the whole pie chart is a household's total number of cultivated hectares, meaning that the fractional multinomial logit model can help to see how changes in market and household characteristics affect the share of land devoted to cotton, maize, sorghum, millet, or secondary crops.

Combining some main elements of the fractional logit and the multinomial logit models to come up with the fractional multinomial logit model is fairly straightforward.<sup>6</sup> The fractional logit model differs from the standard logit model as it treats the dependent variable as an expected value defined by an interval rather than a response probability (Papke and Wooldridge 1996). Similarly, the fractional multinomial logit model must ensure that the expected share of any outcome  $j$  lies between parameters  $A$  and  $B$  and that the sum of shares for all outcomes sums to unity. Mathematically,

$$A \leq E(S_j | x) \leq B, \quad j = 0, \dots, J, \text{ where } A=0 \text{ and } B=1, \quad (3)$$

$$\sum_{j=0}^J E(S_j | x) = 1 \quad (4)$$

This technique permits the evaluation of shares of total farm land instead of the probability of whether or not a crop was cultivated.

The multinomial logit describes a technique for comparing the response probabilities for several categorical variables through use of a pivot outcome, which is the difference between one and the sum of expected shares for all other outcomes. Likewise, the fractional multinomial logit model defines a pivot outcome as well, but again, its dependent variables are fractional outcomes (i.e., crop shares), not response probabilities. Defining  $j = 0$  as the pivot outcome, the fractional multinomial model also must establish expressions for every outcome within the logit framework.

$$E(S_j | x) = G(\beta_0 + \beta_k x_k) = G(z) = \exp(z) / [1 + \sum \exp(z)], \quad j = 1, 2, \dots, J. \quad (5)$$

$$E(S_0 | x) = G(\beta_0 + \beta_k x_k) = G(z) = 1 / [1 + \sum \exp(z)], \quad j = 0 \quad (6)$$

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<sup>6</sup> Again, see Appendix 4 for a summary of the logit, fractional logit, and multinomial logit estimation methods.

Use of the pivot outcome equation (6) to estimate multiple outcomes makes it possible to evaluate the effect of explanatory variables on several crops simultaneously. Therefore, when joined together, the fractional multinomial logit model estimates coefficients which predict the expected share of several categorical outcomes within a defined interval, such as the share of cultivated land that a Malian household devotes to various crops.

By embedding the fractional logit function into the multinomial logit quasi-likelihood function, the econometric model can measure shares of outcomes—not probabilities—in what is a simplified form of the log likelihood function (Mullahy 2011). This new function, as a member of the linear exponential family, uses a quasi-maximum likelihood estimator (QMLE) and is efficient and consistently normally distributed provided the fractional logit function holds true (Ye and Pendyala 2005).<sup>7</sup> The QMLE approach will maximize this new function and, with the assistance of a fractional multinomial logit STATA package (Buis 2008, updated 2012), run until it has converged and is able to predict crop shares.

However, because the multinomial logit estimator requires some normalization, these QMLE estimates will correspond to the coefficients in the multinomial shares model. Thus, it produces coefficients that may be difficult to interpret (Mullahy 2011). For this reason, using the coefficients predicted from an estimation of the fractional multinomial logit model, I calculate average marginal effects for every explanatory variable on each crop outcome, taking into

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<sup>7</sup> For a more detailed description of fractional logit models and the quasi-maximum likelihood technique, see Papke and Wooldridge (1996) or Ye and Pendyala (2005). For specifics on the fractional multinomial logit model as well as information related to specification testing or other multivariate fractional models, see Koch (2010), Mullahy (2011), and Murteira and Ramalho (2012).

account the coefficients for interaction terms when applicable.<sup>8</sup> Section 5.2 will present the estimated average marginal effects, calculated from coefficients estimated with a fractional multinomial logit model, and then discuss their economic meaning.

## **5.2 Presentation of Average Marginal Effects**

Using the data described in Chapter 2, the variables informed by the agricultural household model in Chapter 3, the data described in Chapter 4, and the fractional multinomial logit model explained above, this thesis will now present the model's results and average marginal effects on crop shares due to changes in various explanatory variables.

Drawing from 334 observations, the fractional multinomial model converged on a log pseudo-likelihood of -480.03 with a Wald chi-squared of 2004.73. To control for potential correlation over time within the same household, observations were “clustered” by a household identification number to ensure that standard errors were estimated robustly. The results of the fractional multinomial logit pivoted off of *CottonShare* are provided in the Appendix 7.

Now, this chapter focuses its attention on the average marginal effects of the independent variables on crop shares, as presented in Table 6. Average marginal effects that are statistically different from zero at the 10%, 5%, and 1% levels are indicated with one, two, or three asterisks, respectively; coefficients that are not statistically different from zero at the 10% level or below receive no asterisk. Of the model's 125 coefficients for average marginal effects, only 30 are significant at the 10% level, though some are close.

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<sup>8</sup> See Appendix 5 for a specification of the fractional multinomial logit model in STATA and Appendix 6 for the code used to calculate average marginal effects.



**Table 6: Average Marginal Effects of the Independent Variables (Derived from Results of Fractional Multinomial Logit)**

Log pseudolikelihood = -480.02629

Obs: 334

Wald Chi^2: 2004.7

Prob > Chi^2: 0.0000

|                   | Cotton Share |        |        | Maize Share |        |        | Sorghum Share |        |        | Millet Share |        |        | Secondary Share |        |        |
|-------------------|--------------|--------|--------|-------------|--------|--------|---------------|--------|--------|--------------|--------|--------|-----------------|--------|--------|
|                   | Coef         | Rbst   | SE Sig | Coef        | Rbst   | SE Sig | Coef          | Rbst   | SE Sig | Coef         | Rbst   | SE Sig | Coef            | Rbst   | SE Sig |
| MenPerHct         | 0.0032       | 0.0400 |        | 0.0422      | 0.0267 |        | -0.0714       | 0.0465 |        | 0.0080       | 0.0496 |        | 0.0180          | 0.0452 |        |
| WomenPerHct       | -0.0434      | 0.0464 |        | -0.0014     | 0.0323 |        | 0.0148        | 0.0542 |        | 0.1189       | 0.0597 | **     | -0.0889         | 0.0557 |        |
| YouthPerHct       | 0.0074       | 0.0225 |        | 0.0150      | 0.0246 |        | 0.0424        | 0.0298 |        | -0.0962      | 0.0358 | ***    | 0.0314          | 0.0348 |        |
| InfantsPerHct     | 0.0580       | 0.0292 | **     | 0.0024      | 0.0315 |        | 0.0428        | 0.0512 |        | -0.0347      | 0.0541 |        | -0.0684         | 0.0528 |        |
| %MenInactive      | -0.0817      | 0.0653 |        | 0.0377      | 0.0304 |        | 0.1324        | 0.1031 |        | -0.0841      | 0.0757 |        | -0.0044         | 0.0557 |        |
| %WomenInactive    | -0.0223      | 0.0577 |        | 0.0143      | 0.0343 |        | 0.1054        | 0.0745 |        | -0.0703      | 0.0472 |        | -0.0271         | 0.0501 |        |
| Sprayers          | 0.0202       | 0.0066 | ***    | -0.0013     | 0.0052 |        | -0.0210       | 0.0102 | **     | -0.0275      | 0.0128 | **     | 0.0296          | 0.0141 | **     |
| Plows             | 0.0053       | 0.0071 |        | 0.0063      | 0.0059 |        | -0.0001       | 0.0102 |        | 0.0011       | 0.0108 |        | -0.0126         | 0.0124 |        |
| Oxen              | 0.0071       | 0.0050 |        | 0.0049      | 0.0027 | *      | 0.0030        | 0.0062 |        | -0.0064      | 0.0051 |        | -0.0086         | 0.0065 |        |
| Motorcycles       | -0.0009      | 0.0133 |        | 0.0054      | 0.0088 |        | -0.0270       | 0.0161 | *      | 0.0197       | 0.0122 |        | 0.0027          | 0.0146 |        |
| Bicycles          | 0.0012       | 0.0050 |        | -0.0014     | 0.0038 |        | 0.0057        | 0.0088 |        | 0.0038       | 0.0084 |        | -0.0093         | 0.0082 |        |
| Carts             | 0.0311       | 0.0154 | **     | -0.0037     | 0.0116 |        | -0.0287       | 0.0167 | *      | 0.0015       | 0.0202 |        | -0.0003         | 0.0215 |        |
| %MenLiterate      | 0.0041       | 0.0171 |        | -0.0075     | 0.0192 |        | -0.0292       | 0.0412 |        | -0.0120      | 0.0313 |        | 0.0446          | 0.0326 |        |
| %WomenLiterate    | 0.0250       | 0.0293 |        | 0.0182      | 0.0231 |        | -0.0379       | 0.0481 |        | 0.0013       | 0.0493 |        | -0.0066         | 0.0607 |        |
| Bambara           | 0.0176       | 0.0388 |        | -0.0484     | 0.0119 | ***    | 0.0393        | 0.0517 |        | -0.0132      | 0.0332 |        | 0.0048          | 0.0474 |        |
| Senoufo           | -0.0316      | 0.0244 |        | 0.0009      | 0.0226 |        | 0.0590        | 0.0466 |        | -0.0271      | 0.0351 |        | -0.0013         | 0.0442 |        |
| Peulh             | -0.0076      | 0.0301 |        | -0.0361     | 0.0197 | *      | 0.0677        | 0.0468 |        | 0.0516       | 0.0908 |        | -0.0756         | 0.0664 |        |
| OtherEthnic       | -0.0441      | 0.0305 |        | -0.0523     | 0.0169 | ***    | 0.0106        | 0.0622 |        | 0.1167       | 0.0713 |        | -0.0310         | 0.0356 |        |
| Year_2010         | 0.0635       | 0.0213 | ***    | -0.0096     | 0.0176 |        | 0.0098        | 0.0417 |        | -0.0235      | 0.0398 |        | -0.0401         | 0.0542 |        |
| Village_Tonon     | -0.0328      | 0.0294 |        | 0.1010      | 0.0277 | ***    | 0.1386        | 0.0517 | ***    | -0.1595      | 0.0298 | ***    | -0.0473         | 0.0420 |        |
| Village_Kaniko    | -0.0306      | 0.0247 |        | 0.0404      | 0.0244 | *      | -0.1181       | 0.0418 | ***    | 0.0211       | 0.0334 |        | 0.0871          | 0.0494 | *      |
| Village_TryI      | -0.1290      | 0.0137 | ***    | -0.0161     | 0.0235 |        | 0.0103        | 0.0536 |        | 0.0014       | 0.0338 |        | 0.1335          | 0.0593 | **     |
| Village_Signe     | -0.0664      | 0.0223 | ***    | 0.0286      | 0.0267 |        | -0.0449       | 0.0489 |        | 0.0428       | 0.0497 |        | 0.0399          | 0.0434 |        |
| Village_Gantiesso | 0.0069       | 0.0336 |        | 0.0223      | 0.0189 |        | -0.0742       | 0.0452 |        | -0.0952      | 0.0278 | ***    | 0.1402          | 0.0482 | ***    |
| Village_Simona    | 0.0887       | 0.0382 | **     | 0.0453      | 0.0208 | **     | 0.0156        | 0.0362 |        | -0.0735      | 0.0273 | ***    | -0.0761         | 0.0310 | **     |

**Significance Legend:**

\*\*\* = P<.01

\*\* = P < .05

\* = P < .10

A few other points must be made about the interpretation of the coefficients in Table 6. For non-binary variables, the coefficients represent the mean of the change in crop shares as a result of a marginal change in the explanatory variables for all observations. So for example, the first coefficient for *MenPerHct* under the outcome *CottonShare* is 0.0032, which suggests that a one-unit increase in *MenPerHct*, all else equal, is associated with an average increase of 0.32% for land allocated to cotton across all households, though in statistical and economic terms, this is no different than zero. For binary variables, the coefficients represent the average change in crop shares resulting from a shift in the variables' minimum to its maximum, across all households. Thus, the coefficient for *Bambara* under *CottonShare* is 0.0176, which suggests that—relative to a Minianka household—a Bambara household has an average of 1.76% more land devoted to cotton. The upcoming discussion will highlight coefficients deemed to have economic and statistical relevance to the research questions.

Furthermore, because crop shares must always sum to one—as they are defined by a finite amount of total cultivated hectares—the sum of the average marginal effects for any one variable is zero; in other words, what an independent variable takes away from some crop shares, it has to give to others. Additionally, the average marginal effects of interaction terms are not presented as such a measure does not exist; under the assumption of “all else equal,” an interaction term has no marginal effect as it is only the product of two other explanatory variables. However, the coefficients estimated for the interaction terms by the fractional multinomial logit model were incorporated into the calculation of the average marginal effects for those explanatory variables involved in the interaction term.<sup>9</sup> In short, while the interaction

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<sup>9</sup> Again, see Appendix 6 for the STATA code used to calculate average marginal effects.

terms have no measure of average marginal effect for themselves, the consequences of the interactions are present in the average marginal effects in Table 6.

### *5.2.1 Labor and Land: Household Members per Hectare and Inactivity*

To start, I evaluate the effect of labor and land supply on crop choice and land allocation. Here, variables are expressed in terms of household members per hectares, but for ease of interpretation, the results will be analyzed specifically for households with 6.25, 9, and 12.25 hectares of total cultivated land. These values represent the 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentile of total cultivated land in the sample, which will proxy for a small, medium, and large farm in the following discussion.

The results indicate that every additional adult male per hectare is associated, on average, with a 7.1% decrease in land allocated to sorghum, more than half of which is transferred into maize crop. For every additional male on a small, medium, and large farm, this translates into 1.1%, 0.8%, and 0.6% decrease in the household's share of sorghum, respectively. Thus, this effect seems small considering that the median household has four adult males present, and the effect is surprisingly inconclusive for labor-intensive cotton. However, the draw away from sorghum, which has relatively low input costs, to more marketable food crops—particularly labor-intensive maize—is logical given that more men per hectare is usually equated to more labor per unit of land.

Moreover, every additional adult female per hectare is associated, on average, with a 11.9% increase in land allocated to millet, more than half of which is taken from land allocated to secondary crops. This effect translates into a 1.9%, 1.3%, and 1.0% decrease in a household's share of millet for every additional woman present on a small, medium, and large farm, respectively. Although the median household has four adult females present—as with

men—these effects are greater than those described for adult males per hectare. An average marginal effect linked with an increase in millet share may suggest that women are influential in millet production, though the converse effect on share of secondary crops, which are more often cultivated by women, casts some confusion. Another possibility is that, all else equal, more women per hectare may be the result of more wives among the household's men, and thus a sign of increased wealth. This may be associated with a slight increase in millet share, which is considered more marketable than sorghum.

Another important consideration in a discussion about the effect of labor on crop choice and land allocation is the percentage of adult men and women in a household who are inactive or otherwise unable to assist with farm labor. As is, the results described in the paragraph above assume that all household members are healthy and able to contribute to fieldwork. However, the results find that if an additional 25% of a household's adult men are inactive (i.e., one of the four men in the median household), this is associated with nearly 2.0% decreases in the share of cotton and millet and an opposing 3.3% increase in sorghum share. Further, a 25% increase in the number of adult women who are inactive is correlated with a 2.6% increase in land allocated to sorghum and a 1.8% decrease in millet share. While none of these coefficients for inactivity are statistically significant at the 10% level, an interesting pattern emerges. The slight increases in sorghum at the expense of millet and cotton support the role of sorghum as the “safe” crop, grown by families who are vulnerable to risk and have more mouths to feed with less labor input. Additionally, secondary crops seem to be the least affected, perhaps because inactive household members are most able to contribute to the production of these crops; for example, elderly women are able—and quite skilled at—cracking peanut shells, though this task could be delegated elsewhere if no one was inactive in the household.

Despite providing less (if any) to the labor supply, youth and infants per hectare also affect land allocation of crops, though probably as consumers of crop production. The results suggest that a one-unit increase in the number of children per hectare, ages 6 to 15, is correlated with a 9.6% decrease in land allocated to millet—nearly the opposite effect of adult females per hectare—and small compensating increases in sorghum and secondary crop shares. In a small, medium, and large household, this means that every additional child, ages 6 to 15, decreases millet share by an average of 1.5%, 1.1%, and 0.8%, respectively. This effect seems to counteract that of adult women per hectare even more if one considers that the median household has four youths as well. It may be that these effects will cancel each other out in most cases, but in households where there are many more adult women than youths, these women will often focus on millet production. So conversely, when there are many more youths than adult women, the additional work of caring and feeding these children distracts the women from millet production and lowers its share of total cultivated land.

Finally, a one-unit increase in the number of infants per hectare, ages 5 and under, is linked to a 5.8% increase in a household's share of cotton, which is largely compensated by a 6.8% decrease in secondary crop share, among others. However, this is only a 0.9%, 0.6%, or 0.5% increase for every additional infant on a small, medium, or large farm, respectively, and the median household in the sample had only two infants in the household. Still, the significance behind this result is unexpected, as infants have nothing to contribute to cotton production (though even children as young as eight can help during the cotton harvest), and the cash crop will not directly provide food for them. Possible explanations include that households may be just a bit more likely to grow cotton if they have infants, as these young children may require more cash expenditures related to post-natal care. However, that additional infants take away

from land allocated to secondary crops is expected if women, in fact, are responsible for most secondary crop production, because additional infants requires additional resources (e.g., time) devoted to caregiving.

### *5.2.2 Household Characteristics: Literacy and Ethnic Identity*

Next, I discuss the results related to the effect of household characteristics on land allocation of crops. Derived from variables that represent household traits and not market or resource constraints, these results may provide evidence for or against the agricultural household model. As discussed in Chapter 3, this model states that because smallholder farms in Mali's Koutiala production zone are both producers and consumers of their field crops, due in large part to market failures, they will take into consideration their own tastes and preferences when making crop production decisions. The variables included in the model to represent household characteristics relate to adult literacy and ethnic identity.

Starting with adult literacy, which serves as a measure of education and a possible proxy for motivation and intelligence, the average marginal effects on crop shares in Table 6 resulting from the fraction of adult men and women who are literate are statistically insignificant and thus inconclusive. Still, the results find that a 25% increase in the percentage of household men who are literate (an additional one person out of four) is correlated with a 1.1% increase in secondary crop share and a nearly 0.7% decrease in sorghum share, with all the magnitude of other effects being even closer to zero. The same 25% increase in household percentage of women who are literate is associated with a 0.6% increase in cotton share and 0.9% decrease in sorghum share, with negligible effects for all other shares.

That both measures of household literacy are linked to decreases (albeit small) in sorghum share is not surprising, as one expects that education and the motivated individuals who

seek it likely make a household less vulnerable, possibly because they are able to support the household in other ways. However, the positive effect of male literacy on secondary crops shares and that of female literacy on cotton shares was unexpected, as I had predicted the opposite. First, literate men are able to attain leadership positions within cotton producer associations, so it seemed reasonable that more literate households could become more invested in cotton production through participation in their association. Conversely, I had thought that the largest positive effect for women's literacy would be on secondary crops, since many women's associations tend to simultaneously promote literacy classes and secondary crop cultivation (e.g., gardening), though perhaps this effect is not as influential as expected. Yet, even if women's gardens are in fact a significant factor, it is possible that the household men did not relay this to survey enumerators or that this production occurred in cold season, which is not included in the data. Two other possible explanations remain. First, men often seek training to learn production techniques for secondary crops, meaning that there well could be a relationship between adult male literacy and land allocation to secondary crops. Secondly, the low magnitude and high standard errors for all coefficients in this category do not provide solid evidence to validate any significant inquiry.

Another set of variables in Table 6 contain binary variables representing ethnic identity. The results suggest that, compared to the Minianka ethnic group, many ethnic identities in the Koutiala production zone are associated with a smaller share of cultivated land allotted to maize. All else equal, Bambara, Peulh, and "other ethnicity" households are correlated with a 4.8%, 3.6%, and 5.2% decrease in maize share, respectively, relative to Minianka and Senoufo ethnicities. Both of these latter ethnic groups have inhabited the Koutiala area longer and were more likely present when maize was first introduced and promoted by CMDT, which may help

to explain this difference. Yet, the difference in maize share is not directly proportional to differences in cotton shares between ethnic groups, though the two have overlapping value chains.

Other results are noteworthy though not statistically significant. First, all ethnic groups present in the model are also linked to an increase sorghum share relative to the Minianka group, ranging between 1.1% and 6.7%. Also, all are associated with a decrease in cotton share relative to Minianka households, between 0.8% and 4.4%, except for the Bambara people. This trade-off between cotton and sorghum could be related to cultural identity or generational knowledge sharing, as the Koutiala production zone has long been known for its cotton production and is mostly inhabited by the Minianka people. The trade-off also makes sense if other ethnicities are often more vulnerable to risk, and thus preferred a safer crop like sorghum to one with high investment costs. For example, it is possible that minority groups, having immigrated to the area, may not be as established as the Minianka people, which may result in financial insecurity and having to farm on second-choice land; such conditions make it difficult to consider anything but staple crop production. Finally, Peulh and “other” ethnicity households are found with 5.1% and 11.6% greater shares of millet, along with 7.6% and 3.1% smaller shares of secondary crops, respectively. This more closely aligns to what one might find further north in Mali—from which many of these people originate—where an arid climate is more suitable to millet than production of secondary crops. Ethnic identities only serve as one measure of a household’s tastes and preferences, but evidence that these variables actually affect crop shares justifies, to some degree, the agricultural household model.



### 5.2.3 *Capital: Farming Equipment*

The correlation between capital (i.e., farming equipment) and crop shares are also estimated in the model. The results suggest that each additional pesticide sprayer owned by a household is correlated with a 2.0% increase in cotton share and a 3.0% increase in the share of secondary crops, which comes at the expense of a 2.1% and 2.8% decrease in sorghum and millet share, respectively. On average, these coefficients can explain the difference in the composition of 1/10 of total cultivated hectares between a household with zero sprayers (21% of the sample) and another with two (26% of the sample); the latter will devote it to cotton and secondary crops in place of millet and sorghum. This outcome is logical considering that the sprayer is normally used for pesticide application on cotton and some types of secondary crops and rarely on coarse grains. Input-intensive maize may be the exception, though the effect of additional household sprayers on its share of farm land is inconclusive.

Next, results for the number of draft plows and oxen owned by the household, which incorporates an interaction term between them, imply that they have very little average marginal effect on any outcome, especially considering that the median household has only one plow and two oxen to pull it. Compared to a household with no plows or oxen, the median household in the sample is linked to 2.0% and 1.6% increase household share of cotton and maize, respectively, made up for by a 1.2% decrease in millet share and a 3.0% decrease in secondary crops, though only one of the coefficients is significant at the 10% level. Still, the results do not contradict expectations, as many farmers do not risk investing in the production of cotton and maize if they cannot properly prepare their fields, though some are able to borrow or rent; this would lead to an average increase in the share millet and especially secondary crops, the latter of which are usually cultivated by hand tools and benefit the least from oxen-drawn equipment.

Overall, these results provide evidence that owning capital that makes cotton and, to a lesser extent, maize less labor intensive—as it enhances labor productivity—affects a farmer’s planting decisions. Still, given that these tools are required for cotton and maize production, the magnitudes are smaller than anticipated. While ownership of tools may be linked to higher shares of crops that use those tools, it is certainly far from the dominant determining factor.

#### *5.2.4 Transport*

It was theorized that access to modes of transportation that may reduce transportation and even transaction costs might affect crop shares. While over half of households in the sample do not own a motorcycle, for those that do, each additional motorcycle is associated with an average 2.7% decrease in total cultivated land allocated to sorghum. This is largely made up for by a 2.0% increase in millet share and an even smaller increase in maize, though neither increase was statistically significant. Ownership of bicycles had a smaller effect, even when considering that the median household owned two, and the results here are inconclusive. At best, they suggest that an additional bicycle may be linked with an almost 1% decrease in secondary crop share, which is unexpected given the occasional use of bicycles to transport smaller loads of secondary crops to and from local markets. Overall, both modes of transportation seem to have limited explanatory power.

The effect of owning a cart to transport goods to market—or also from the fields to the household—was also examined. Table 6 shows that an additional cart was estimated to be correlated with a 3.1% increase a household’s share of cotton, most of which is taken from a 2.9% decrease in sorghum share, with minimal changes to shares of maize, millet, and secondary crops. These results make sense if the cart is primarily seen as a piece of farming equipment that assists with production rather than a way that reduces transport costs to market. Carts are very

useful for transporting organic and inorganic fertilizer to cotton fields and during the harvest, when the plucked cotton needs to be kept off the ground and sent to a dry location. However, because CMDT sends semi-trucks to collect the cotton harvest from each producer association, the cart does not significantly reduce transportation or transaction costs to market. So while possession of carts may influence crop choice and land allocation, it does not necessarily do so as predicted in Chapter 3.

#### *5.2.5 Time and Location*

Variables representing time and location were mainly included in the model as controls, but their results offer valuable insights as well. First, the results indicate that in the 2009/10 farming season, households located in the Koutiala cercle increased the share of their land allocated to cotton by 6.4% compared to 2008/09, an effect that reflects the increase of cotton hectares planted between that time throughout the Koutiala production zone, as seen in Figure 2.5. Even though the price of cotton fell 30 FCFA per kilo between these two years (roughly 60 US dollars per metric ton), this upward trend represents a recovery from a major producer strike in the 2007/08 growing season (Mali Assessment 2011). However, this increase in cotton share was done mostly at the expense of secondary crops and millet, with minimal effects on maize and sorghum, though an average 0.4 hectare increase of total cultivated land between these years may also explain some change in crop shares without necessarily assuming that land was redistributed to different crops.

Continuing, the collective set of village dummy variables showcases some interesting results, especially when one considers a primary difference between them—ease of market access—which applies to the villages Kaniko, Try I, and Signe, as described in Table 3. Again, ease of market access refers to the fact that these villages are approximately twenty kilometers or

less from Koutiala, the region's central market, whereas others are farther away. The findings suggest that, relative to the first village of Nampala II (the base village), which has difficult access to Koutiala's markets, these three villages devote less land to cotton and sorghum; specifically, Try I and Signe have smaller shares of cotton by 12.9% and 6.6%, respectively, and Kaniko and Signe have smaller shares of sorghum by 11.8% and 4.5%, respectively. To compensate for these changes, Kaniko, Try I, and Signe all grow higher shares of millet, especially relative to the other villages with poor market access, Tonon and Gantiesso. Furthermore, Kaniko and Try I have higher shares of secondary crops (relative to Nampala II): 8.7% and 13.4%, respectively.

The patterns for the villages farther from markets are a bit more varied. Relative to Nampala II, households in the second village of Tonon are associated with a 10.1% increase in maize share and a 13.9% increase in sorghum share, on average, which is balanced by a 16.0% decrease in millet share and small predicted decreases of cotton and secondary crops as well. While the results for Gantiesso have in common with Tonon a high decrease in millet share (9.5%), its households are correlated with 14.0% increase in secondary crop shares and a 7.4% decrease in sorghum share.

Collectively, these results suggest that the villages with better market access to Koutiala have more in common than those that do not, which is possible for a couple reasons. First, because Kaniko, Try I, and Signe are all within a relatively small radius of Koutiala, it is more likely that the villages are similar in terms of climate and soil quality. Conversely, the locations of Nampala II, Tonon, and Gantiesso are more spread out and characteristically diverse, which may help to explain differences between them, such as the average household's share of sorghum, which may differ between Tonon and Gantiesso by as much as 20%.

The second reason is that access to Koutiala's markets may provide certain incentives that motivate a specific crop choice and land allocation in its surrounding villages. Consider the decline in cotton share for Kaniko, Try I, and Signe. It may be that access to Koutiala and its markets gives households a greater opportunity to earn income through coarse grain or secondary crop production, which may eliminate the need to produce cotton in order to earn cash. Also, a key benefit of participation in the cotton industry is that CMDT helps to reduce transportation and transaction costs for crop sales and input procurement by driving semi-trucks out to its village—no matter how remote. In Simona, where one farmer remembers his grandfather walking 100 kilometers to sell cotton in Koutiala, this service continues to be an influential incentive because they have difficult access to large and functioning markets otherwise. However, this service is less valuable when a trip to a substantial market can be made daily by donkey cart. Thus, the correlation between villages with better market access and smaller shares of cotton is logical, yet revealing for those working at CMDT.

Furthermore, households in the villages of Kaniko, Try I, and Signe have generally higher shares of millet and secondary crops. For millet, this may be because a strong export demand from Cote d'Ivoire makes it a viable and marketable cash crop, especially for those near the markets of Koutiala, a regional trade hub. But unlike millet, sorghum does not currently have a similar export demand. Additionally, if households are already selling their millet in Koutiala, they face fewer transaction costs to buying other cereals to diversify their diet, providing another incentive for them to specialize in millet production. Better access to Koutiala's market also makes production of secondary crops more promising since fruits and vegetables are often in the highest demand in the city and, if not, its markets are full of traders willing to take products to sell in remote markets. For example, farmers who produce watermelons would likely sell them

and living close to the city would reduce the high transportation and transaction costs involved in moving the large and perishable fruit, making its production more profitable.

Altogether, the magnitudes and significance of the coefficients for the village dummy variables suggest that village location seems to explain much more about the effect of transaction costs on crop choice and land allocation than ownership of motorcycles, bicycles, and carts. However, better market access had a relatively inconclusive effect on maize. This may be because of the overlap between the cotton and maize value chains; many farmers use credit through CMDT to purchase fertilizer for maize production. So perhaps while better market access may make maize more appealing as a cash crop in its own right, the negative effect of market access on cotton production, and by extension input procurement for maize production, balances out its effect on maize shares. However, clearly maize is grown more in some villages, such as Tonon and Kaniko, perhaps due to favorable geographic or climatic conditions.

Finally, results under the location variable *Village\_Simona* represent a seventh village in the Yorosso cercle that I surveyed in the following 2010/11 growing season. So, compared to the base data, it is both a different time *and* location, and one that is more economically isolated. Relative to Nampala II in 2008/09, the results suggest that Simona households have increased shares of cotton and maize by 8.9% and 4.5%, respectively, which is offset by decreases in shares of millet and secondary crops of 7.4% and 7.6%, respectively. Not unlike some of the villages in the Koutiala cercle described above, the average household in Simona differs in its land allocation decisions for about 15% of its land, relative to the average household in Nampala II, all else equal. Additionally, these results reinforce patterns discussed above given how Simona's economic isolation and distance from Koutiala give it incentives to produce cotton along with maize instead of larger shares of potentially marketable millet and secondary crops.

Not surprisingly, only 4% percent of households formally sold millet that year and only 8% of households formally sold any coarse grain.

### **5.3 Application of Results to Example Households**

To conclude this chapter, I will apply the average marginal effects from Table 6 to a couple of example scenarios, now that the coefficients have been discussed individually. This will demonstrate the usefulness of the average marginal effects when trying to predict total crop shares for specific cases. In particular, I want to examine differences between a wealthier, larger household and a small, disadvantaged household. For simplicity, both cases will be from the same year, village, and ethnic group, dismissing the need to consider these coefficients in the calculation. The predicted crop shares for both households, and the differences between them, highlight many of the results discussed above.

The first household has six adult males, eight adult females, eight young boys and girls over the age five, and four children under five. The household farms on 16 hectares and owns two sprayers, three plows, six draft animals, two carts, two motorcycles and three bikes. Furthermore, three adult men are literate along with two of the adult women, and only the elderly grandmother is considered inactive. These figures are slightly better than the average for a household of this size. The second household falls below the average 2008/09 Minianka household in the dataset. It is comprised of two adult males, two adult females, three boys and girls over five, and three children under five. The household farms on six hectares with one plow, one ox, one bicycle, but does not own a sprayer, motorcycle, or a cart. One adult male is literate and none are inactive. Again, these numbers are slightly lower or more disadvantaged than a typical household of this size.

Assuming that both households belong to the same year, village, and ethnic group, the larger first household is estimated to allocate 13% more land to cotton and 4% more land to maize, in exchange for 15% less share of sorghum, relative to the smaller second household. The differences between shares of millet and secondary crops are relatively small at 1% less for the first household, evening out all crop share differences to sum at zero. These differences between the aggregate average marginal effects for two households emphasize the role of cotton and, to some extent, maize as a cash crop for households with the proper farming equipment and labor supply.

For the sake of another example, consider if the smaller and disadvantaged household now has one inactive male—an unfortunate but possible scenario. This one change greatly affects the differences in crop shares between the two households. Now, the larger household is estimated to allocate 17% more to cotton share and 22% less to sorghum share, relative to the smaller second household, with small differences in maize, millet, and secondary crop shares that even out all differences to sum at zero. The strengthening of the divide between cotton and sorghum shares highlights sorghum's role as a crop for vulnerable households with many mouths to feed relative to the land, labor, and other inputs available.

Finally, while there are some very significant average marginal effects on millet and secondary crop shares, they did not emerge in this application. This may be because the values chosen here for specific variables canceled out any variable-specific positive or negative impacts. For example, coefficients for the effect of the number of women and youth per hectare on millet share are both statistically significant and impressive in magnitude, but in opposite directions; thus, these effects mostly balance out here since the households in each scenario had similar headcounts of women and youth. Furthermore, determinants of millet and secondary crop



shares—along with maize shares—may have a lot to do with village or ethnic group. For example, as a marketable crop, millet sees much higher shares in villages closer to Koutiala. Yet because both scenarios were equal by year and location, these differences in millet share did not emerge.

The primary purpose of this exercise was to demonstrate that the average marginal effects on crop shares add up, though some clearly have more effect than others. It presented two scenarios of realistic, yet different, households in the Koutiala production zone and predicted how their crop shares may differ relative to each other. In the second example, the model was able to predict land allocation differences for almost a quarter of the household's total cultivated land, even though these families could have been neighbors. Using the coefficients, it is also possible to predict the expected crop shares for different years and ethnic groups represented in the data.

## **CHAPTER 6: CONCLUSIONS**

To conclude this study, I will present a summary of its methodology and then make policy recommendations based on relevant findings. Also, limitations will be discussed, including aspects from survey design to data manipulation. Lastly, I will suggest opportunities for future research that build on this thesis and previous works.

### **6.1 Summary of Methodology**

This thesis began with a research question concerning land allocation of field crops in Mali, the understanding of which is important for improving household food security and preparing for challenges facing Mali's cotton industry. Specifically, policymakers need to know how certain market and household characteristics affect planting decisions of cotton, coarse grains, and secondary crops. Whereas many studies examine this issue one crop at a time—perhaps building on a supply response model or estimating the probability of crop adoption with a logit or probit model—I undertook a different approach.

First, I applied the agricultural household model to my understanding of Mali's Koutiala production zone, which established a framework that assumed that household farms face a utility maximization problem subject to a budget, production, and time constraint. Thus, their land allocation function is determined by expected prices, family labor, inputs, land area, access to capital, risk, transaction costs, household characteristics, and alternative sources of income. Variables were selected to represent these factors, employing data from two survey rounds of 150 households in Mali's Koutiala cercle and an additional round of 50 households from the neighboring Yorosso cercle a year later. In all, 350 observations represented seven villages.

Variables consisted of household members per hectare, inactivity of adults, available farming equipment, literacy, ethnic identity, village location, and available modes of transport.

To estimate the relationship between these factors and land allocation decisions in the data, Chapter 5 employed a fractional multinomial logit. This technique builds on a standard logit by allowing for categorical, non-binary, dependent variables whose values are fractions which sum to one. For my purposes, the share of land allocated to cotton, maize, sorghum, millet and other “secondary” crops served as the five dependent variables, all of which, when combined, equaled the total number of hectares cultivated by a household. The fractional multinomial logit results were estimated through quasi-maximum likelihood using the fractional multinomial logit package in STATA. The resulting average marginal effects of the explanatory variables on each crop share category were presented and discussed.

## **6.2 Summary of Findings**

This thesis’s research question asked which determinants were responsible for land allocation of cotton, maize, sorghum, millet, and secondary field crops. Overall, the most influential sets of variables were those representing ethnic identity and village location, the latter of which may be due to proximity to markets in Koutiala. Villages closer to Koutiala were closely associated with much higher shares of millet and lower shares of maize, sorghum, and especially cotton. Finally, the effects of ethnic identity varied by group, but compared to the Minianka majority, most grew a higher share of millet and smaller shares of maize and, to a lesser degree, cotton and secondary crops. Meanwhile, variables sets representing family and farm size, literacy, farming equipment, and modes of transportation had significant results for some variables on particular outcomes, but were not as revealing overall.

Specifically, the model estimated that the key determinants of increased land allocation to cotton were the number of infants per hectare and the number of pesticide sprayers and carts owned by the household. It was discussed that while infants cannot assist with cotton production nor consume it directly, this link may be because families with young children expect many out-of-pocket expenses—from medicine to future school fees—that require cash, which can be earned through cotton production. Also, since cotton growing has high start-up costs, the ownership of capital needed for successful cotton production, such as carts and sprayers, helps farmers decide to grow more of it. Village location was also influential, suggesting that those households living in a village closer to Koutiala planted smaller shares of cotton, perhaps because better access to Koutiala’s markets makes it easier to trade and earn income with other goods. Although CMDT transports all inputs and output to villages where cotton is grown, proximity to Koutiala also makes these efforts to reduce farmer’s transaction costs less of an incentive.

Above all else, the key determinants of land allocation to maize were ethnic identity and the number of adult males and youth, between the ages of 6 and 15, per hectare. Households belonging to the Bambara, Peulh, or another “other” ethnic group devoted less land to maize relative to Minianka and Senoufo households, perhaps reflecting a cultural or historical preference for maize. Additionally, that more household members per hectare was correlated with higher maize shares is expected as its high-yielding potential is good for families with little land and many mouths to feed, as long as they possess the labor supply to support its production. Finally, owning capital (e.g., plows or oxen) also helped to increase maize shares—as with cotton—as farming equipment significantly increases labor productivity for tasks that are necessary for successful maize production.

Earlier discussions in this thesis of sorghum and millet reviewed how these coarse grains have very similar subsectors, but the results imply that the determinants for how much land is devoted to each differ greatly. Increased sorghum share is associated with more infants per hectare, higher percentages of inactive adults in the household, and it often serves as the trade-off for increased shares of cotton and maize for additional capital. Further, its share greatly decreases as the number of adult men per hectare goes up. It seems to be a crop for vulnerable households with many mouths to feed, but not enough capital or labor to consider planting more maize; certainly, this is the picture that emerged from the example scenarios in Section 5.3. While I would have expected millet to fulfill a similar role, the results suggest that it is not so much a safety crop as a marketable one. In fact, millet shares are inversely related to the percentage of household adults who are inactive, and increased shares of millet are highly correlated with villages in close proximity to Koutiala, where well-functioning coarse grain markets exist to export millet to Cote d'Ivoire or elsewhere. So while their subsectors may be similar, the determinants of land allocation to sorghum and millet have distinct differences.

Finally, key determinants of land allocation to secondary crops vary a lot by location as well. This may be due to increased access to thriving markets—all three villages near Koutiala had higher shares of secondary crops—or due to geographic differences; the village of Gantiesso, which also had high shares of secondary crops, may have been located near a river that made rice production possible. On the other hand, smaller shares of secondary crops were linked to increased number of women and infants per hectare and some ethnic groups, especially the Peulh people. Since it was thought that women are mostly responsible for secondary crop production, the negative effect of adult women per hectare on secondary crop shares was unexpected, though this same negative effect attached to infants per hectare is logical after considering that infants

require time and energy from women that then could not be used in crop production. Perhaps households with fewer women, and thus fewer infants, are more likely to devote land and other resources to secondary crops, which have higher investment start-up costs.

### **6.3 Policy Recommendations**

These results, along with some personal observation and evidence from other sources, can help inform recommendations for Malian agricultural policymakers. Since determining the shares of various crops is a zero-sum game—that is, a situation in which all gains are someone else’s losses—the recommendations for improving cotton and coarse grain production oppose the other’s. Yet, if households responded to new incentives by clearing new fields and planting additional hectares of crops or increasing adoption of fertilizer to boost yields, it is possible that both cotton and coarse grain production can increase overall. Of course, such changes cannot be analyzed using this thesis’s methodology, as it only examines crops shares, but should be kept in mind.

For Mali’s cotton company CMDT, the primary recommendation is stressing the importance of not losing their institutional advantage, which has been helping households attain farming equipment, offering fertilizer procurement through cheap cotton-backed credit, covering transport of inputs and output, and paying farmers shortly after harvest. First, CMDT has historically assisted farmers in attaining cotton-farming equipment, such as sprayers, plows, draft animals, and donkey carts, all of which help explain higher shares of cotton production associated with ownership of such equipment. However, as older tools deteriorate and new households are established in the Koutiala production zone, there must be ways to help farmers overcome the steep start-up costs attached to cotton production. Offering fertilizer procurement and covering transport also help reduce transaction costs for farmers, a relevant factor for

isolated villages without easy access to Koutiala's markets. Finally, as stressed by Theriault (2010), the cotton industry must make predictable and timely payments to its suppliers who rely on this income soon after the harvest. Failure to do so is what led to a cotton strike in 2007/08 and likely explains why, in the results, cotton shares increased in 2009/10 relative to 2008/09 despite the fact that the producer price of cotton dropped by 30 FCFA between those years (Mali Assessment 2011). These perks of participating in the cotton industry are considered part of its expected incentives package and thus need to be met or expanded in order to maintain or expand cotton production.

For those looking to reform the cotton industry, a pertinent question is whether or not this expected incentives package is sustainable. If so, what would be the result of cutting certain services; which has the highest cost-to-benefit ratio? Unfortunately, answering these tough questions is beyond the scope of this thesis. However, it is important to reiterate that while some villages in the Koutiala production zone seem to be parting ways with CMDT, other villages are still dependent on it. I assert this from experience, having lived in Simona for almost two years, and this claim is supported by the significantly positive correlation between cotton share and the variable *Village\_Simona*. Additionally, interviews conducted for this thesis affirm that many villages in the Yorosso cercle have a similar dependency on the cotton industry. Moreover, many farmers there either fail to understand or underestimate CMDT's financial woes and their potential implications. For them, talk of cotton reform is frightening, as it threatens the primary livelihood they have been raised to understand. Any transition or change must not only consider sustainability and profitability, but perhaps more importantly, dependent farmers' well-being and ability to adapt. Transition can also be helped through communication (by radio, extension agent,

or otherwise) and clear and predictable timetables that give farmers the ability to revisit their household's utility maximization problem.

For agricultural policymakers hoping to boost coarse grain production and sales, the results have some usefulness as well. With regards to maize, it remains cultivated on the least amount of hectares, especially by ethnic groups not native to the area—despite tremendous growth overall throughout Mali in the last decade. This may be because of varying taste and cooking preferences between ethnic groups or because CMDT extension, which introduced and promoted maize in this area years ago, has dwindled and may not continue to encourage maize production as much. Either way, if Mali hopes for Koutiala to help in increasing the country's share of maize within total cereal production, it may help to increase promotion of maize as a delicious and marketable crop, along with providing resources for farmers to learn more about its cultivation. From experience, I believe that radio programs may be a successful starting point as they are non-confrontational, inexpensive to broadcast, and capable of reaching a wide audience.

Moreover, the results suggest that while sorghum and millet exhibit similar value chains, each has a different role in the Koutiala production zone. Sorghum is the “safe” crop—grown more by vulnerable households—and millet is the marketable coarse grain. This result is telling given that much of the policy discussion now is about the growing demand and marketability of maize as opposed to millet. These differences in the role that sorghum and millet play should be studied more, either through qualitative or quantitative analysis, to determine if these differences exist only in the dataset or truly represent trends across the production zone, or even the entire county. Additionally, policymakers should continue work that reduces transaction costs for coarse grain markets as the results suggest that better accessibility to markets enable households to cultivate greater shares of coarse grains (particularly millet) relative to cotton. For sorghum,



reduced transaction costs would also make it easier for vulnerable households to purchase this “safe” crop, which in turn may encourage greater market participation. Overall, any action taken now to strengthen the sustainability of these coarse grains markets helps to reduce household vulnerability to potential changes resulting from the restructuring of the cotton industry.

One question that came to mind frequently while serving as a Peace Corps Volunteer in this area was: if coarse grains were put on the same playing field as cotton—that is, if they all had the same incentives package—what would crop shares and production look like? To do this, one approach is to reform the cotton industry, as is being discussed anyway, so that it either offers fewer services or that those services can apply to more aspects of coarse grain production. Another is to reform agricultural support markets so that they become viable alternatives to services offered by CMDT. For example, is it possible to reform, support, promote, or raise awareness of Mali’s microfinance institutions, so that they offer more farm-friendly financial products that are competitive with CMDT’s loans for fertilizer? This could be done if payments on loans could be delayed until cereal prices were higher (around April or May), giving farmers an opportunity to maximize their profit from coarse grain production before paying off their debt. Moreover, many people still do not understand the financial mechanisms offered by microfinance institutions, and actions aimed at educating farmers about their benefits and appropriate use of a loan or bank account could make these options more accessible to rural households.

Furthermore, the results identify some helpful patterns for secondary crops that may be of use to policymakers. Again, secondary crops can be beneficial in the farming system because, even though they likely limit specialization in cotton or a coarse grain, their successful production can diversify a household’s income portfolio or diet, which can help to reduce risk

and can improve household nutritional intake. Yet, the results indicate certain types of households that are associated with lower shares of secondary crops: those from economically isolated areas like Simona, minority ethnic groups, and those with more women per hectare and children under the age of 6 per hectare. Results to variables representing village location indicated that secondary crops shares seem to vary much by geographic location, regardless of market access, and are primarily grown when there is extra family labor to dedicate to it or suitable environmental conditions (e.g., a river to grow rice and other water-intensive crops). Continued education to rural audiences on the nutritional importance, potential use, marketability, and different production techniques of certain secondary crops may boost their production over time while at least exposing households to the idea that these are essential for a well-balanced diet, especially for their children.

Lastly, the focus on the village of Simona in this study also highlights a need to conduct more research in the Yorosso cercle, which has consistently higher cotton adoption rates among households than those in the Koutiala cercle. Also, since the relationship between the cotton and coarse grain subsectors is stronger in this area, its population will be more vulnerable to sudden changes as a result of the CMDT restructuring. Therefore, special consideration must be given to the coarse grain subsector, and particularly maize, in the Yorosso cercle throughout cotton industry reform as the food security of Simona, and its neighboring villages, may depend on it.

## **6.4 Limitations**

Since every economic model seeks to simplify a complex reality while maintaining explanatory power, it is bound to have limitations from the data it employs or the model itself. This thesis is no exception, and in fact, most of the fractional multinomial logit's limitations have already been discussed. Theoretically, its measurement of crop shares disregards the effect

of fertilizer and careful maintenance on production, giving the impression that hectares planted to specific crops is always a zero-sum game. Secondly, it tells us which variables higher or lower shares of particular crops but not necessarily why this is the case, whereas other models may facilitate the use of crop-specific variables to help explain these correlations. However, these limitations were discussed and kept in mind throughout the interpretation.

Secondly, other possible limitations of this study result from human errors made during the collection of the data. This could be the fault of the respondent, who may have provided an estimate without knowing for sure. Another possibility is that the respondent lied in an attempt to impress or evoke pity from the enumerator, who could have been perceived as a government official or non-profit worker. Sometimes enumerators make errors whether by mistake or intention. Especially if a question is embarrassing or one outcome is typically given for over 90 percent of respondents, enumerators may just fill it in without asking. These were some of the issues that emerged for the 50 surveys I conducted in Simona, where I trained local enumerators who spoke the native Minianka, although as discussed in Chapter 4, steps were taken to minimize collection errors. For example, I encouraged enumerators to meet with a group of the household's men over a round of tea to ensure that their farmers were giving input, since some household heads are no longer active in agricultural production. Similar strategies were adapted for the Koutiala survey rounds too. Still, the possibility of some error exists.

Along the same lines, in hindsight it would have been beneficial to include or revise additional variables to use in the present analysis, but because they were not collected, they could not be included here. This includes a host of village-level variables such as distance to paved road, nearest weekly market, or access to a microfinance institution, all of which would have enriched the analysis of the results for village location dummy variables. Also, it would

have been valuable to know how much households earned from alternative sources of income and whether this was earned outside the village or not. Another excluded variable was some representation of last year's food stock at the time of planting, which may affect crop shares as households aim to offset expected food shortages. Lastly, the survey asked whether each family member put in a morning, afternoon, or full-day of farm labor to draw up its labor supply estimates, but it did not disaggregate this request for different times of the year (e.g., planting, weeding, or harvest). In the future, more accurate estimates of family labor, perhaps lagged one year, may have a place in this model.

Finally, as in many studies of agriculture in the developing world, these results would be strengthened with additional data. Fifty observations per village is close to, but not quite enough, for us to be truly confident that it fully represents the village, and certainly seven villages out of 45 communes leaves room for misrepresentation. The timeline in which these surveys were conducted also creates room for additional error, though these were controlled for as best as possible in the model.

## **6.5 Future Research**

This thesis began with two primary motives. One was to provide insights to Malian policymakers as they attempt to address food security and cotton industry reform in the Koutiala production zone. In this regard, there is certainly more research to do. While examining crop shares and land allocation has been a useful exercise, there are various other approaches that have been and should be done in order to understand changing trends of crop preference, input adoption, market failures, and child nutrition.

Two emergent transitions in Mali make future research there more relevant than ever. The first is the much-discussed cotton industry reform, the future of which is uncertain, but the

impact of which could be significant as the cotton industry has been a monopsony there since Mali's independence. Thus, continued research on Mali's cotton subsector, along with its social and economic impacts, may be useful to policymakers and should address at least three topics. First, understanding which of CMDT's services are needed and valued the most by rural farmers could assist with reform efforts, especially if the industry becomes privatized. Secondly, it is important to understand which existing markets have developed which compete with CMDT, or its services, especially those that may have enabled some households to not rely so heavily on the cotton industry in recent years (e.g., fertilizer merchants, alternative cash crops). In other words, what alternatives have helped bring about, or emerged in response to, a decline in participation in the cotton industry, and how might these alternatives be encouraged or improved within the broader reform effort? Finally, such research should maintain a special focus on cotton-dependent households, like many of those in the central part of the Yorosso cercle, which can inform strategies to assist communities in adapting to potential change in the cotton industry. Research that exclusively focuses on villages closer to the city of Koutiala for the sake of convenience are at risk of overlooking vulnerable cotton-dependent communities, which—as this thesis has argued—face a different set of economic circumstances.

The second and more troubling transition is that of the country's political instability and civil unrest after its coup d'état in late March of 2012 that was quickly followed by a rebel takeover of Mali's three northern-most regions. This has resulted in uncertainty in the South, made worse by the threat of economic sanctions, and horrific killings and crimes against civilians in the North. Thankfully for the villages in the Koutiala production zone, their lives and land are safe, and the rains this year are good, though some villages have relied on food aid. However, given that the final outcome of this struggle remains uncertain, there will certainly be a

need to reexamine food security to see if progress has regressed or continues as it has over the last decade.

The other motive of this study was to develop a new method of modeling household land allocation for various crops in developing countries. To do this, we adapted the agricultural household model for use in Mali's Koutiala production zone and applied the relatively new fractional multinomial logit framework. While neither is without its limitations, some described just above, the overall model had definite explanatory power and was useful in discussing determinants of crop choice and planting at the household level. What is needed now is additional work applying this model to different circumstances. Within Mali, it can be applied to other regions and their alternative crop portfolios. Another idea is to open up the dependent variable representing shares of secondary crops to see how the explanatory factors affect peanuts, sweet potatoes, sesame, and vegetables differently. In fact, use of the model on a generous dataset in any developing country can help to provide evidence for theoretical discussions of the agricultural household model, such as the extent of the effect of transaction costs or inter-annual credit restraints. As it can compare all crops simultaneously, it can serve as an additional tool to study the farming system on the household farm, which continues to be the most fundamental economic unit in the majority of the developing world.

## **APPENDICES**

## **Appendix 1: The Household in the Koutiala Production Zone**

The term “household” is used extensively throughout this paper, though the standard definition of this term varies greatly across cultures. In Mali, a household is typically a large patriarchal social structure including an average of three generations in which relationships are relational or marital. However, depending on family divisions or migrations, household size can vary greatly. For example, during the 2009/10 growing season, households in Simona had an average of 18.9 members, though the smallest household was roughly 4 members and the largest (by far) was 84. Each household normally has one established location close to a village center and another settlement near its fields. The latter is inhabited during the farming season in order to increase labor efficiency on the farm.

Authority and privileges within the household are granted with age and are gender-specific. The head of the household, the eldest male, is traditionally granted the final say for all household decisions. One Malian friend confided that he believed the fiancé of his daughter to be a bad man, but could not break the engagement or protest because his elder brother, the household head, had already negotiated the marriage. Thus, many household-level development studies consider characteristics of the household head as explanatory variables for a given dependent variable, though many household heads work with the other adult males in the family on complicated matters. For example, an elderly man will make his decisions along with his sons, who currently manage the household’s fields, or an elder brother consults with his younger siblings to maintain family peace. While conferring with a woman is not unheard of, it is by and large the exception to the rule.

The respected men within a household also make most decisions regarding family consumption. They are responsible for managing the household’s finances and food stock in



general, especially the share for their wives and children. In a traditional village such as Simona, a woman will not take grain out of storage without receiving her husband's permission first, and similarly, she must ask her husband for money before going to market and be ready to explain her expected purchases. As a result of this weighted decision-making, respected men often consume better goods than the rest of the family. Since meats and vegetables are still considered luxury goods in many communities, these are mostly consumed by the men when they eat first, leaving less for women and children. This is not done out of spite, but out of tradition and unawareness (the nutritional value of these foods is not widely recognized). When these men, and particularly the head, make household decisions, every member of the household is considered, but the hypothetical weights given to each individual is determined by the man's moral and social values.

In terms of labor, the role of men in the household is dictated by the seasonal calendar. In the rainy season, which goes from June to September, rainfall is adequate for the planting and maintaining of crops. These few months are busy for an entire family, but particularly for men, who often wake at dawn and work until dusk with only a two-hour break at lunch. For this reason, these few months are alternatively called the farming season. Moreover, this time leading up to the harvest is also known as the hungry season, when many households run low on last year's supply, and any available excess grains can sell for a high price.

Then, October to January, known as the cold season, becomes increasingly dry and cool, which are good conditions for crop harvest and gardening. Normally, there is enough food for everyone during this time, but prices are also lower since grain supply is abundant. So during this time, men have to take stock of the harvest and carefully strategize how they will manage their food and finances for the year. Additionally, cold season is an opportunity to make mud bricks,

and then construct or repair structures, because the next six months without rain will allow them to dry and harden.

Finally, from February to May, the hot season is the time when villagers (but mostly men) take leisure as high temperatures make people lethargic. Many rest and spend their evenings at weddings until the early rains in May begin to alert people of the start of the next crop cycle. It is important to note that men rest to various degrees during hot season; some seem to spend an entire two months in the shade, while others continue to build up their own compound, volunteer for a community project, or work in village as a service provider (e.g., carpenter, blacksmith, or mechanic). Of course, this latter group can work all year, but get most of their business during the dry seasons from December to May.

The role of women within a southern Malian household is mostly restricted to food preparation, child-rearing, and some agricultural activity. With permission from their husbands, women may also participate in associations or income-generating activities, such as gardening or shea butter production. While this work is seen as inferior or even degrading for a man, it was accepted by nearly all Peace Corps Volunteers that Malian women work far longer and harder than men, whose farm labor is seasonal. Development efforts have focused on Malian women not only to promote gender equality and empowerment, but also because of evidence that income earned by women often has a greater positive effect on children's health than men's income (Tefft, Kelly, Wise and Staatz 2003). Yet, effective partnering with women requires an appreciation of their time and decision-making constraints.

Similar to the men, respect among women is a function of their age and marital status, the latter of which is complicated by practiced polygamy that allows (not requires) men to marry up to four wives according to Islamic law. Keeping this in mind, it is easy to see why these

households can grow to be so large. In Simona, the respected patriarch of an established family had four wives, over a dozen children, and could not recall the number of his grandchildren. Such size makes it more difficult for the adult men to agree on household decisions, but also can provide a safety net, especially for widows, their children, and the elderly.

A support network and safety net is particularly important in remote villages where residents have limited access to basic goods and services. Theoretically, every village has its own water pump, maternity, and elementary school, but misunderstandings between villagers, the government, and non-profits about who is responsible for maintaining these facilities can lead to situations in which they are not functional. Next, there is a series of other public goods, such as middle schools, microfinance banks, and water towers that are given to villages able to convince a benefactor of their need. However, larger institutions such as hospitals, high schools, and radio towers are only found in important cities, such as Yorosso or Koutiala.

Weekly markets are not held in every village, and although Simona has one, it offers significantly less than some larger villages in the Yorosso cercle. For most households, getting to a larger market requires some form of transportation, such as a donkey cart (if buying or selling a lot), bicycle, or motorcycle. Finally, public transportation to Koutiala and beyond is only accessible on paved roads. This means if the household's village is located off the roads, privately owned transport is required to access it as well. These obstacles, which vary by village, are some of the challenges that increase risk and transportation costs for rural households.

## **Appendix 2: Fertilizer and Credit for Staple Crop Production**

In CMDT's Koutiala production zone, there are three types of fertilizer most commonly used for staple crop production. Complexe Coton is intended for use on cotton, Complexe Céréale is intended for use on coarse grains, and urea can be applied on both. But while all of these crops can benefit from the appropriate fertilizer, cotton and maize are especially dependent on fertilizers in order to be profitable. However, even after a large fertilizer subsidy was instituted in 2008, these fertilizers can still be expensive for a Malian household; a bag of subsidized fertilizer costs a minimum of 12,500 FCFA (roughly 25 US dollars), although before the subsidy it cost anywhere between 18,000 and 20,000 FCFA (roughly 36 and 40 US dollars, respectively). Part of the problem is that nearly every household faces a cash constraint around July or August (during hungry season) when fertilizer is needed. In order to purchase fertilizer, households must choose between two suppliers and two methods of payment. The two suppliers are CMDT and market vendors and payment can be made in cash or on credit. Since the CMDT mechanism is complex, we will begin by discussing procurement through a market vendor.

If a household has cash and is willing to spend it, it may purchase the fertilizer from a market vendor directly. However, since these fertilizer vendors tend to be closer to paved roads and growing towns, the remote household may incur high transport costs. Even in Simona's rural weekly market, established shops (boutiques) and vendors sold various input products including weed-killer, fungicide, and insecticides. However, these vendors did not sell Complexe Coton, Complexe Céréale, or urea fertilizers. Still, they are noteworthy because they represent a developing infrastructure that may be able to handle all input distribution in the future, even in remote rural areas. Purchasing on cash through a market vendor was an attractive option for only one farmer in Simona, where historically CMDT was the sole supplier of fertilizer and other

inputs. When asked why they refrained from selling fertilizers, these market vendors responded that no one was willing to buy from them. The price was too high relative to household disposable incomes in the period before the harvest when cash was low and needed to purchase food and maintain farming equipment.

Thus, an alternative is that a household purchases fertilizer from a vendor after applying for a loan through a microfinance institution, but this is rarely done. First, at an interest rate around 20 percent, this is a far more expensive line of credit than going through CMDT. Further, the perceived punishment for failing to follow through on payments is as severe as imprisonment. Because of this risk, use of a microfinance loan for fertilizer procurement may not be the most attractive option for households growing cotton, though it may be reasonable if cotton production is deemed unprofitable and cash is unavailable.

On the other hand, the CMDT mechanism allows farmers to purchase their inputs on credit. Sacks of fertilizer have a premium rate that is just over 7 percent, raising the total cost of a fertilizer sack to 13,415 FCFA (roughly 27 US dollars). Essentially the mechanism stipulates that each year, farmers can receive credit for up to 74,125 FCFA per hectare of cotton (as of 2010) in order to procure coarse grain fertilizer and cotton inputs, which is then deducted from their cotton payment after the harvest for a small premium. Otherwise, households can still purchase at the base rate if they are willing to pay in cash. Either way, CMDT covers the input's transport cost to the village. Additionally, current policy allows households to purchase inputs for coarse grains through the same system. Particularly for households interested in expanding maize production, this mechanism simplifies fertilizer procurement by reducing transaction costs and the need for cash or microfinance credit in June or July, as the hungry season approaches.

Furthermore, due to CMDT structural reforms made in 1974 (Theriault and Sterns 2012),

all financial exchanges between the producer and CMDT are made through a producers' village association, including debts. Therefore, if an elephant crushes your cotton crop and you do not produce enough to repay, this debt will not put you in prison, but makes you responsible to your association. Then according to local custom on debt repayment, you will have repay as the association sees fit. Thus, the association serves as a producer network and safety net, which does not exist for most other crops.

For Simona farmers, evidence suggests that purchase of fertilizer through CMDT was a very attractive option. Households that cultivated cotton in 2010/11 acquired all three types of fertilizer exclusively through CMDT. Only one farmer, who was unable to rent the livestock, equipment, and labor required to plant cotton that year, purchased fertilizer for maize at the weekly market after making a special order in advance. It is also important to highlight that 97.7 percent of all fertilizer purchased for coarse grain production in Simona was placed on maize fields during the 2010/11 farming season.

One option that was avoided by Simona farmers was relying on credit from Kafo Jiginiw, a microfinance institution with a branch in Simona that was open during weekly market. The low demand for its lending and bank services was a frustration that Kafo Jiginiw officials expressed at a public meeting (Kafo Jiginiw 2011). It was pointed out that of the eight villages in the Yorosso cercle that have a bank branch, Simona's had the lowest amount of money in active accounts as well as the lowest number and value of loans taken out. Indeed, over half of the accounts had less than 2000 FCFA in them (roughly 4 US dollars). According to villagers, credit from Kafo Jiginiw was not desirable because of the need to make regular early payments rarely made financial sense as good prices for coarse grains—another possible source of income—were not available until April. As discussed, such loans also had a high interest rate and stiff

repercussions for defaulting, though over 98 percent of Kafo Jiginw loans taken out in Simona were paid back on time. Given that all Simona farmers who grew cotton in 2010/11 used their CMDT credit to purchase fertilizer for both their cotton and coarse grains, it is clear that the Kafo Jiginiw line of credit was not preferred.

While only one person in Simona purchased fertilizer from a market vendor using cash, the figure was slightly higher in the six villages surveyed in the Koutiala cercle. Of the 849 market transactions made by households to procure fertilizer in 2009/10 and 2010/11, 10.8 percent were made in cash and to a market vendor. Still, purchasing fertilizer on credit through CMDT was the most common method, making up 84.5 percent of transactions. The fact that this rate is higher than the average adoption rate of cotton suggests that those who grew cotton were more likely to purchase fertilizer and/or purchase it for more than just cotton. Most of the remaining transactions were made with “other” fertilizer suppliers, and those made with market vendors using credit were fewer than one percent. These statistics provide some evidence on the PROMISAM’s hypothesis that the cotton industry may positively affect coarse grain productivity by selling coarse grain fertilizer on cheap, cotton-based credit.

### **Appendix 3: Development of Agricultural Household Model**

This appendix provides a summary of some of the background research that brought about the development of the agricultural household model adopted by this thesis. The first section presents the basic model, as popularized by Singh, Squire, and Straus (1986), which is void of considerations for risk behavior, market failures, and transactions costs. The second section examines more recent literature that attempts to incorporate these concepts, namely transaction costs, relying heavily on Omamo (1998) and de Janvry, Fafchamps, and Sadoulet (1991).

#### *A.3.1 Generalized Agricultural Household Model*

In designing a model specific to the Malian context, it is necessary to discuss the literature and determine which resource constraints and market failures are relevant factors for crop choice and land allocation for Malian households. The following section presents the foundational model and then discusses market failures. Since almost every new author in the literature has unique labels for their variables, I will be consistent in my representation while still paraphrasing the contribution of their work.

Building on the early work of Barnum and Squire (1979) and later Singh, Squire, and Strauss (1986), I assume a static agricultural household model in which the primary objective of the household, as discussed, is to maximize expected utility during a given production cycle as a function of consumption of farm-grown consumption products  $X$  (e.g., millet or milk), a vector of other consumption goods  $Y$  (e.g., clothes or radios), and leisure  $H$ :

$$\text{Max } U = f(X, Y, H) \qquad \text{utility maximization function} \qquad (\text{A.1})$$

However, households maximize expected utility subject to constraints on income, time, and production technology. First, the cash income constraint dictates that the value of goods  $X$



and  $Y$  consumed by the household cannot exceed household cash income. Simply put, assuming the absence of credit or savings, the household cannot spend more than it earns in a given production cycle. Income from agricultural production is the value of agricultural output  $P_x Q$  minus the cost of inputs  $P_v V$  and total labor inputs net of labor contributed by the family  $L - F$ . Formally,

$$P_x X + P_y Y \leq P_x Q - P_L(L - F) - P_v V + \pi_y \quad \text{cash income constraint} \quad (\text{A.2})$$

where  $P_x$  and  $P_y$  are a vector of prices for farm-grown goods  $X$  and other goods  $Y$ , respectively;  $Q$  is a vector of the household's agricultural output;  $P_L$  is a market wage;  $L$  is total labor input and  $F$  is family labor input (if positive,  $L - F$  indicates hired labor);  $P_v$  is a vector of prices associated with a vector of non-labor inputs  $V$ ; and  $\pi_y$  represents profits from other activities. Since agricultural production is the principal income-generating activity for most Malian households, this equation is key for describing the relationship between household consumption (on its left) and production (on its right).

Equation (A.2) also predicts how trade affects a household's budget constraint in the Singh, Squire, and Strauss model. Applying basic algebra to equation (A.2) produces the following:

$$P_y Y \leq P_x(Q - X) - P_L(L - F) - P_v V + \pi_y \quad \text{alternative cash income constraint} \quad (\text{A.3})$$

In equation (A.3), the difference between  $Q$  and  $X$ , that is household production and consumption of a particular farm-grown crop, is its market surplus. When positive, it indicates that a household's production exceeded its own demand, allowing additional income to be earned through its sale. When negative, a household's production fell short of its own demand, leading to purchases from the market. In the case of cotton, households consume very little if any of their crop, so their market surplus is positive and revenue is generated. However, if a household

consumes maize but does not grow any, then its market surplus is negative, though there is also no labor or input costs. In the case that a particular crop is both sold and purchased at market—a common outcome resulting from cash flow constraints or financial mismanagement—the market surplus indicates whether the household earned a net gain or loss from market transactions. Overall, this equation suggests that households should focus on their comparative advantage in order to make profit, and if their comparative advantage lies in agricultural production of a particular crop, then they should produce and sell this crop in order to avoid being a net buyer of agricultural products overall.

Next, the Singh, Squire, and Strauss model hypothesizes that each household faces a time constraint, which is straight-forward. Very simply, households must divide their total time  $T$  between leisure  $H$  and family labor  $F$ , which includes on-farm and non-farm labor that may generate profit  $\pi_y$  from other activities. However, later authors (Benjamin 1992) define family labor  $F$  in two separate variables to distinguish between labor that goes toward agricultural production  $X$  as well as off-farm labor  $Y$ . Though it is not in the original model, the same is done to equation (A.4):

$$H + F + O = T \qquad \text{time constraint} \qquad (A.4)$$

where  $O$  represents off-farm household labor.

Not only does this better represent the necessary trade-off between work and leisure, which in the case of tea drinking may also increase one's social capital in the community, it also illustrates the challenge of labor allocation between various activities. For example, if one household member can find profitable employment in a city, this can significantly reduce a household's production potential and alter their crop choice and land allocation decisions. Thus,

a decision has to be made by the household head as to whether it is best for the individual to take the city job, though this may affect crop production.

By aggregating all labor through an entire production cycle, what the constraint is still unable to capture fully is the intra-seasonal labor requirements. For instance, more family labor is required for the task of harvesting cotton relative to that needed for applying pesticides to cotton fields. However, most research prior to Schultz (1964) assumed there was always excess labor on the farm since they often observed households when labor was not in the highest demand. Because of intra-seasonal labor demands, household develop strategies to increase this labor supply around this time, including calling back a son who works off-farm or pulling children out of school. This can make aggregate family labor input, on or off-farm, difficult to estimate.

Finally, in addition to cash income and time constraints, each household is limited by agricultural output  $Q$  as a function of various inputs that make up the production technology:

$$Q = f(L, V, A, K) \qquad \text{production constraint} \qquad (A.5)$$

where the new variables  $A$  and  $K$  represent a household's total land and available capital (e.g., farming equipment), respectively.

Note that all of the variables included on the right-side of equation (A.5) are capable of being changed by the household, but over different time frames. Even within a given production cycle, a household is able to adjust crop inputs, such as fertilizer, and perhaps even labor supply during peak times. On the other hand, total land and available capital are more likely changed in the long term. A household is typically only able to clear a few new hectares of land each year, assuming that it has already taken steps to acquire the land through the village chief, and new

equipment or repairs are considered larger expenditures. Still, all of these factors are likely to affect crop choice and land allocation.

If the time and production constraints are substituted into the cash income constraint, utility can be maximized with only a single constraint. This process yields a set of first-order conditions that equates the marginal revenue products for labor and fertilizer to their respective market prices. It also predicts a “profit effect” that occurs when an increase in food prices also increases household income. This effect is normally ignored in traditional demand models, yet it certainly can reduce or even outweigh the negative income and substitution effects that result from a price increase.

Thus, whether or not a price change helps a household depends on whether it is a net buyer or seller of food products; net sellers can attain additional income through higher prices by the “profit effect,” whereas net buyers may suffer through overall reduction in income. Since more often than not, the poorest of households fall into the latter category, many governments attempt to maintain low food prices through policy interventions. Mali is no exception, but since cotton is not consumed by its farmers, it is often viewed as the income-generating commodity. Either way, this discussion, which stems from the Singh, Squire, and Strauss model, highlights its potential usefulness in discussing market accessibility and participation. It is no surprise then that the extensions of the agricultural household model are mostly related to the issue of missing markets and other market failures.

### *A.3.2 Market Failures and the Agricultural Household Model*

The most severe flaw with the generalized model presented above is that it assumes access to perfect markets (i.e., those free of transaction costs and fully capable of hedging risk)—an assumption that does not even truly hold in developed countries, and certainly not in Mali.

Even for farmers participating in the cotton industry, which simplifies market transactions for inputs, outputs, and credit through CMDT, their production incentives for cotton can still be affected by failures in other related markets, such as those for coarse grains. Market failures also provide a rational explanation for non-separability, as high transaction costs create a gap between prices observed in markets and the prices at which trade is profitable for particular households. These reasons call for a reassessment of the Singh, Squire, and Strauss model and its predictions on marketed goods.

The most extreme form of a market failure is when a market does not exist. In most of the Koutiala production zone, this is essentially the case of the labor market for agricultural production. In Simona, the village in which I served as a Peace Corps Volunteer, I recall only one household that had hired one man to maintain a large garden year-round—and this household was headed by one of the most respected men in the region. Most households draw mainly from their own members' labor supply during times of peak labor demand, as discussed above. Less often, friends and neighbors may work together on each other's fields—exchanging a nearly equivalent amount of labor for both parties—or may assist in special circumstances, such as when church-goers help the pastor plant his crop. However, given the absence of any real formal or informal labor market, this study will assume that all labor input needs are met by the household; that is, in equation (A.2),  $L - F$  always equals 0. This assumption does not eliminate the need for the time constraint (A.4), as it continues to define  $L$  in the production constraint (A.5) and present possible off-farm labor needs  $O$  that bring in household income through other activities. However, in upcoming discussions concerning how missing markets affect the Singh, Squire, and Strauss model, labor will be removed as a cost of production in variations of the cash income constraint, though household farm labor  $F$  will be included as a factor of production.

Even where markets exist, high transaction costs and other barriers may prevent profitable trades that would otherwise occur from happening. For example, consider a Peace Corps Volunteer who hears of one market vendor selling watermelon for a reasonable price, but at a stall across town—a 45 minute walk. That is a 1.5 hour commitment, half of which is spent carrying a watermelon down a hot and crowded street, and the other option, a taxi, will cost five times more than the watermelon itself. Similarly, for a rural household, the ease of transaction often has to do with the distance between the farm and market as transport in much of the developing world is expensive and unreliable. From Simona, the nearest paved road was seven kilometers and the nearest large market town was twenty kilometers, only open on Mondays. In Simona, transaction costs were a key factor in household decision-making.

Recognizing the importance of such costs in understanding the rationale of the rural poor, Omamo (1998) integrated transactions costs into the Singh, Squire, and Strauss model, citing studies which show that they discourage trade and can influence household-level marketing incentives and decisions (de Janvry, Fafchamps, and Sadoulet 1991). His change is simple: his budget constraint states that the cost of all products consumed plus the transaction costs of buying them must be less than or equal to the value of all products produced minus the transaction costs of selling them; for either a purchase or a sale, the transaction costs decreases the household income level. Hence, modifying equation (A.2) and retaining the cost of inputs (not accounted for in Omamo's model):

$$P_xX + TC_{bx} + P_yY + TC_{by} \leq P_xQ - TC_{sx} - P_vV - TC_{bv} + \pi_y \text{ transaction costs} \quad (A.6)$$

where TC represents a transaction cost for purchases (subscript b) and sales (subscript s). I also included a variable for any potential transaction cost associated with purchasing inputs. Admittedly, the variable TC covers a broad spectrum. In cases for which the price of goods X

and Y are estimated from anywhere other than the household's market, TC may include price changes incurred by the market's middlemen. For example, a merchant purchasing coarse grain will reduce his farm-gate price beyond his profit margin to account for the cost of transporting the grain to its place of sale. Further, de Janvry and Sadoulet (2006) improve this by modeling both fixed and variable transaction costs, the latter being added to a good's market price, but Omamo's simpler model is adequate for my purposes.

A primary contribution of equation (A.6), according to its author, is that it summarizes the trade-off between the gains from specialization and increased transaction costs that affect a rural household's decision to diversify its crops—a tension first identified by North (1981). Rearranging equation (A.6) reveals that:

$$TC_{bx} + TC_{by} + TC_{bv} + TC_{sx} \leq P_x(Q - X) - P_vV + \pi_y - P_yY \quad \textit{diversification} \quad (A.7)$$

In words, the profits earned from all household activities X and Y, minus whatever is spent on other market goods, must be greater than all the transaction costs of buying market goods (including inputs) and selling off household production. If true, then rational households will try to avoid market transactions that are particularly expensive, such as the buying or selling of coarse grain, which includes finding a trustworthy merchant, bargaining over the price, researching the actual price, and still accepting a somewhat adjusted price to account for the merchant's transportation fees. Therefore, in villages where transaction costs are high, the model predicts that farmers are more likely to produce their consumption demand themselves (i.e., production is partially determined by consumption preferences). Where this is true, a household's preference for variety and nutrition requirements often lead them to diversify their crops—as long as the difference in profit from producing one crop over the other is less than the transaction costs required to sell the more profitable one and subsequently purchase the latter.

Since this thesis is attempting to predict crop selection and land allocation, the potential effect of transaction costs on crop diversification is an important factor to include in the econometric model.

Finally, two specialized extensions of the agricultural household model discussed by de Janvry and Sadoulet (2006) attempt to capture how market failures for seasonal credit and risk affect production decisions. Seasonal credit constraints are modeled by adding a slight premium to all sales and purchases representing the shadow price of liquidity, and risk requires inter-temporal modeling to analyze household preference for credit and savings. Additionally, Dorward (2011) recently modeled seasonal food rationing in rural households by dividing up key consumption and production factors into separate variables representing before and after the harvest. Arguing that a flaw of previous models is the assumption that households only aim to produce future consumption, he predicts that current survival needs—possibly present in the pre-harvest “hunger” season—may compromise production goals. Such circumstances may lead a household to harvest its coarse grains early before the crop has fully matured. Or if the family is predicting a household food crisis prior to the planting season, a family may allot more land to a faster-growing crop, and perhaps plant earlier, in order to meet pre-harvest consumption needs. These factors, while difficult to model, are important to consider when selecting choice dependent variables that may determine how farmers allocate land to various crops.



## Appendix 4: Description of Logit, Fractional Logit, and Multinomial Logit Models

This appendix has three sections, the first of which reviews the standard logit model. The second and third sections cover the fractional logit and the multinomial logit model, respectively. Please see the body of the text in Section 5.1 for a description of the fractional multinomial logit method employed by thesis.

### *A.4.1 The Logit Model for Binary Response*

The econometric model used in this paper is more complicated than the basic logit model, so a brief review is necessary before proceeding. To begin, a logit model can be used to estimate response probabilities for binary independent variables. Its main feature (along with the probit model) is that it defines the independent variable, a probability, through a function whose values are between zero and one. This makes it an improvement over employing Ordinary Least Squares (OLS) to regress a response probability with a Linear Probability Model (LPM), which runs the risk of predicting probabilities that are negative or greater than one due to its linear and unbounded nature. While the LPM states

$$P(y = 1|x) = \beta_0 + \beta_k x_k, \text{ and } \beta_k = \partial P(y = 1|x) / \partial x_k, \quad (\text{A.8})$$

the logit model restrains the outcome of the explanatory variables using the function  $G$ , where

$$P(y = 1|x) = G(\beta_0 + \beta_k x_k) = G(z), \text{ and } G(z) = \exp(z) / [1 + \exp(z)]. \quad (\text{A.9})$$

Under this function, the response probability is always between zero and one. (Note that in a probit model, which will not be discussed further here,  $G$  is the standard normal cumulative distribution function).

Next, to estimate a logit model, I use maximum likelihood estimation (MLE) technique instead of OLS, as it automatically accounts for heteroskedasticity. To obtain my estimator,

which is conditional on the explanatory variables, I need to find the density of  $y$  given  $x$ , which can be written as

$$f(y|x;\beta) = f(y|z) = [G(z)]^y [1 - G(z)]^{1-y}, y = 0,1. \quad (\text{A.10})$$

Thus, when  $y = 1$ , I get  $G(z)$  and when  $y = 0$ , we get  $1 - G(z)$ . Finally, to get the estimator, I take the log of the above equation in order to obtain the log-likelihood function:

$$\log(\beta) = (y)\log[G(x)] + (1 - y)\log[1 - G(z)]. \quad (\text{A.11})$$

By summing equation (A.11) for all observations—under the assumption that all observations are independent and identically distributed random variables—I calculate a log-likelihood equation for the sample. Once maximized, this sample log-likelihood equation produces the logit estimator  $\beta$  (Wooldridge 2006). This overview provides a foundation for explaining the technicalities of the following variations and how they differ from the original logit model.

#### *A.4.2 The Logit Model for Fractional Response*

In their seminal work, Papke and Wooldridge (1996) adapted the logit model for fractional response variables, which differ from binary variables in that instead of equaling either outcome A or outcome B, they are equal to or fall into the interval between A and B. Therefore, the model does not attempt to determine the probability of  $y$  given  $x$ , but the *expected* value of  $y$ , *bounded* by two values A and B, given  $x$ . For example, proportion of weekly hours spent working, participation rates in a voluntary pension plan, or share of farm land devoted to cotton could all be fractional dependent variables, because they are bound between zero and one hundred percent, hereafter simplified as one.

Because fractional response variables are bounded, determining their expected value using OLS has similar consequences as applying the LPM to binary dependent variables; as discussed above, the linear nature of the regression may potentially predict values that lay

outside the established bounds. For example, through OLS, one may find that given a particular set of household characteristics, a farmer may devote -6 percent of his land to cotton, which is an awkward outcome to explain. As with the standard logit model for binary outcomes, it is important to ensure that the predictions for fractional dependent variables remain bounded.

As Papke and Wooldridge (1996) discuss, one alternative is to transform  $y$  into a log-odds ratio within the OLS linear function, so that

$$E[f(y)|x] = E(\log[y/(1-y)] | x) = \beta_0 + \beta_k x_k, \quad (\text{A.12})$$

but this presents two problems. First, even a well-defined model in this form makes it difficult to recover the expected fractional value, since estimation of this equation yields the expected value of the logged odds ratio. Secondly, while this transformation does bind the dependent variable *between* zero and one, the equation does not hold true if  $y$  is equal to these bounds (e.g., if one of the shares is zero or one). Therefore, since many households choose not to grow a particular crop—meaning the share of that crop is zero—this alternative seems far from optimal.

This is where I can apply the logit framework from above, applied to the circumstances of fractional dependent variables:

$$E(y | x) = G(\beta_0 + \beta_k x_k) = G(z), \text{ and } G(z) = \exp(z)/[1 + \exp(z)]. \quad (\text{A.13})$$

In addition to binding the expected value by zero and one, without excluding the possibility of it equaling these values, the advantages to this transformation are that it makes no assumptions about how the dependent variable is obtained or the data's sample size. Furthermore, the logit framework allows us to develop an estimator for  $\beta$  through the Bernoulli log-likelihood function, which again, is

$$\log(\beta) = (y)\log[G(z)] + (1 - y)\log[1 - G(z)]. \quad (\text{A.14})$$

Once summed for all observations and subsequently maximized, this provides a quasi-maximum likelihood estimator (QMLE) of  $\beta$  that is both consistent and easy to calculate. In applying this technique to data evaluating participation rates in 401(k) pension plans, Papke and Wooldridge (2009) found their method to be robust and a better estimator than the linear model alternatives.

#### *A.4.3 The Logit Model for Multinomial Response*

The logit model can be extended to instances where the response  $y$  has more than two categorical outcomes. For this study,  $y$  will represent five different categories of crop types. While these alternatives may be assigned labels, such as the integers zero through four, these assignments are arbitrary and are in no particular order. The purpose of the model is to determine the probability that the dependent variable will be a certain categorical outcome given the independent variables. Thus, in mathematical terms

$$P(y = j \mid x), j = 0, 1, 2, \dots, J. \quad (\text{A.15})$$

In this case, the probability of growing a particular crop, whether it is cotton, maize or another, for a given plot of land fits this description and is likely to vary as a result of changes in market and household characteristics present in the explanatory variables.

A key facet of this expression is that it assumes that the explanatory variables do not change for each alternative  $J$ . Rather, the set of  $x$  variables is specific to the household but not to a given outcome. Therefore, it assumes that factors affecting crop choice are limited to market and household attributes that could affect all possible crops, not to variables that could only influence a particular crop without any effect on another. If crop-specific variables were included, the model would have to be further generalized and become a conditional logit model. However, the conceptual model in the previous chapter presents variables that could potentially

affect all possible outcomes in this study. Hence, maintaining the same explanatory variables for each alternative does not pose a problem.

Continuing, as the dependent variable is bounded between zero and one as a probability, it is necessary to apply the logit function from above, so that

$$P(y = j|x) = G(\beta_0 + \beta_k x_k) = G(z) = \exp(z) / [1 + \sum \exp(z)], \quad j = 1, 2, \dots, J. \quad (A.16)$$

Notice that the denominator of the logit function now requires summing for all possible  $j$  outcomes, and that if  $J = 1$ , we would simply return to the binary logit model. Also note that the summing excludes the outcome  $j = 0$ . This is because it is necessary to set up  $j = 0$  as the pivot outcome, which will allow for estimating the effect of the explanatory variables on the probability response of outcome  $j$  *in relation to* the probability response of outcome  $j = 0$ . Otherwise it would be impossible to determine the coefficients within our system of equations.

Since it is assumed that a categorical outcome must be chosen, it follows that the response probabilities must sum to one. Thus, it is known that the probability that  $y = 0$  is the difference between one and the sum of all other response probabilities. Therefore using the identity that defines all other response probabilities above in (A.16), this means

$$P(y = 0|x) = 1 - \sum G(z) = 1 - \sum \exp(z) / [1 + \sum \exp(z)] = 1 / [1 + \sum \exp(z)]. \quad (A.17)$$

Given (A.17), I can now use the probability response for outcome 0 as a pivot for the other outcomes. If the above identities (A.16) and (A.17) hold true, then

$$P(y = j|x) / P(y = 0|x) = \{\exp(z) / [1 + \sum \exp(z)]\} / \{1 / [1 + \sum \exp(z)]\} = \exp(z), \quad (A.18)$$

or with a log transformation

$$\log [P(y = j|x) / P(y = 0|x)] = z = \beta_0 + \beta_k x_k. \quad (A.19)$$

As with the standard logit model, these coefficients are best estimated by maximum likelihood after summing the equation for all observations in the sample (Wooldridge 2001).

## **Appendix 5: Specification of the Fractional Multinomial Logit Model in STATA**

To apply our econometric model to the dataset, I will employ the fractional multinomial logit STATA package authored by Maarten Buis (2008, updated 2012). The program fits the data to a fractional multinomial logit through quasi-maximum likelihood and, for this reason, implies the robust option. The package also includes some post-estimation tools that can display marginal effects and discrete changes, which may be utilized here.

Furthermore, it was described in Chapter 4 that the dataset consists of 150 households from the Koutiala cercle surveyed in 2008/09 and 2009/10, creating a total of 300 observations. In addition, 50 households from Simona in the Yorosso cercle were surveyed in 2010/11, making 350 observations in all, 50 from each of the seven villages. However, because the same 150 households represent 300 observations, this needs to be controlled for when calculating the robust standard error. Even though there is a dummy variable for the 2009/10 season to account for changes over time, there may still be unexplained traits that are unique to a particular household that make it partial to dividing its crop shares in a specific way. In other words, these observations are not independent from each other because they come from the same household. Thankfully, STATA's "cluster" option calculates the standard errors by group—in this case by household identification number—so that the standard errors are robust to arbitrary heteroskedasticity and serial correlation within households.

The notation used by the fractional multinomial logit package for a simple estimation is “fmlogit (dependent variables), eta(independent variables).” Thus, if I incorporate the variables chosen from Chapter 4 that follow from the agricultural household model, I get the following:

```
fmlogit CottonShare MaizeShare SorghumShare MilletShare SecondaryShare,
eta(MenPerHct WomenPerHct YouthPerHct InfantsPerHct Interaction1 %MenInactive
Interaction2 %WomenInactive Interaction3 Sprayers Plows Oxen Interaction4
Motorcycles Bicycles Carts %MenLiterate Interaction5 %WomenLiterate Interaction6
Bambara Senoufo Peulh OtherEthnic Year_2010 Village_Tonon Village_Kaniko
Village_TryI Village_Signe Village_Gantiesso Village_Simona)
cluster(Household_ID)10
```

Note the use of the cluster option on each household to control for endogenous correlation within observations from the same household.

---

<sup>10</sup> Where Interaction1 = WomenPerHct\* InfantsPerHct, Interaction 2 = MenPerHct\*%MenInactive, Interaction 3 = WomenPerHct\*%WomenInactive, Interaction 4 = Plows\*Oxen, Interaction 5 = MenPerHct\*%MenLiterate, and Interaction 6 = WomenPerHct\*%WomenLiterate.

## Appendix 6: STATA Code for Calculation of Average Marginal Effects

To calculate average marginal effects, code was written in STATA to predict the changes in specified outcome given a marginal change in each explanatory variable (and applicable interaction terms). This was then bootstrapped for 50 iterations to estimate a meaningful standard error. The following code was used to calculate one average marginal effect for one outcome—in this case, the average marginal effect of *MenPerHct* on *CottonShare*. Note the incorporation of relevant interaction terms when calculating the overall average marginal effect.

```
program drop _all

program my_ape_MenPerHct, rclass

quietly fmlogit CottonShare MaizeShare SorghumShare MilletShare SecondaryShare,
eta(MenPerHct WomenPerHct YouthPerHct InfantsPerHct Interaction1 %MenInactive
Interaction2 %WomenInactive Interaction3 Sprayers Plows Oxen Interaction4
Motorcycles Bicycles Carts %MenLiterate Interaction5 %WomenLiterate Interaction6
Bambara Senoufo Peulh OtherEthnic Year_2010 Village_Tonon Village_Kaniko
Village_TryI Village_Signe Village_Gantiesso Village_Simona) cluster(Household_ID)
predict share_hat1, pr outcome(CottonShare)

    gen temp1 = MenPerHct

    gen temp2 = Interaction2

    gen temp3 = Interaction5

replace MenPerHct = MenPerHct + 0.0001

replace Interaction2 = MenPerHct*%MenInactive

replace Interaction5 = MenPerHct*%MenLiterate

predict share_hat2, pr outcome(CottonShare)

    replace MenPerHct = temp1

    replace Interaction2 = temp2

    replace Interaction5 = temp3
```



```

gen mfxMenPerHct = (share_hat2 - share_hat1)/0.0001

summarize mfxMenPerHct

    return scalar ape = r(mean)

    drop share_hat1 temp1-temp3 share_hat2 mfxMenPerHct

end

bootstrap ape_MenPerHct = r(ape), rep(50) seed(123) cluster(No_expl)

idcluster(record_No_expl) nowarn:my_ape_MenPerHct

clear all

```

## Appendix 7: Fractional Multinomial Logit Results Pivoted off of Cotton Share

Table A.1 displays the results from the fractional multinomial logit model using *CottonShare* as its pivot outcome. In Chapter 4, it was discussed that in order for the fractional multinomial logit to work—or any multinomial logit—it needs for one category to be the pivot outcome from which all coefficients are based. Changing the pivot outcome does not change the effect of one variable on a particular crop share, but only the perspective from which this effect is observed. Thus, the difference in value between coefficients will not change if the pivot changes, but the numerical values will as the each new pivot response shift what is defined as zero. For this reason, if the coefficient on Y2, pivoted on Y1, was .05, the coefficient on Y1, if pivoted on Y2, would be -.05. However, while all of the coefficients describing the effect on one crop share relative to another can be derived from one table, the robust standard errors do vary for every pivot outcome.

While not strictly consistent with the quasi-maximum likelihood estimation approach, which returns expected crop shares in levels, one can interpret the coefficients in this Table A.1 directly in terms of a logged share ratio. Given the multinomial logit functional form for expected crop shares, the logged expected share of a crop relative to that of the pivot crop—in this case, cotton—is given by:

$$\log [E(S_j | x) / E(S_0 | x)] = z = \beta_0 + \beta_k x_k. \quad (\text{A.20})$$

Thus,  $100 * \beta_k$  is the percent change in a crop's expected share relative to that of cotton for a marginal one-unit change in  $x_k$ . If this value is negative, the crop's share decreases relative to that of cotton, while if this value is positive, the crop's share increases relative to that of cotton.

**Table A.1: Fractional Multinomial Logit Results Pivoted off of CottonShare**

Log pseudolikelihood = -480.02629

Obs: 334

Wald Chi<sup>2</sup>: 2004.7

Prob > Chi<sup>2</sup>: 0.0000

|                             | Maize Share |         |     |  | Sorghum Share |         |     |  | Millet Share |         |     |  | Secondary Share |         |     |  |
|-----------------------------|-------------|---------|-----|--|---------------|---------|-----|--|--------------|---------|-----|--|-----------------|---------|-----|--|
|                             | Coef        | Rbst SE | Sig |  | Coef          | Rbst SE | Sig |  | Coef         | Rbst SE | Sig |  | Coef            | Rbst SE | Sig |  |
| 1 MenPerHct                 | 0.9667      | 0.5167  | *   |  | 0.3652        | 0.5894  |     |  | 0.5566       | 0.7122  |     |  | 0.3656          | 0.8698  |     |  |
| 2 WomenPerHct               | -0.4804     | 0.8017  |     |  | -1.0650       | 0.7762  |     |  | -0.4102      | 0.8846  |     |  | -1.4508         | 0.8711  | *   |  |
| 3 YouthPerHct               | 0.0839      | 0.2296  |     |  | 0.0636        | 0.1916  |     |  | -0.4840      | 0.2318  | **  |  | 0.1174          | 0.2593  |     |  |
| 4 InfantsPerHct             | -0.7767     | 0.6522  |     |  | -1.0736       | 0.5945  | *   |  | -1.8323      | 0.6846  | *** |  | -1.8809         | 0.7757  | **  |  |
| 5 Interaction: (2) x (5)    | 0.9365      | 1.4106  |     |  | 1.7754        | 1.1853  |     |  | 2.7099       | 1.2861  | **  |  | 2.3026          | 1.3273  | *   |  |
| 6 %MenInactive              | 2.2720      | 1.2488  | *   |  | 1.9097        | 1.6170  |     |  | 0.3501       | 1.1397  |     |  | 1.8023          | 1.4719  |     |  |
| 7 Interaction: (1) x (6)    | -3.1859     | 2.3939  |     |  | -2.2233       | 3.0794  |     |  | -0.3254      | 2.7253  |     |  | -3.0942         | 3.4149  |     |  |
| 8 %WomenInactive            | -0.1169     | 0.7208  |     |  | -0.1586       | 0.6526  |     |  | 0.0007       | 0.7115  |     |  | -0.5220         | 0.7602  |     |  |
| 9 Interaction: (2) x (8)    | 0.9700      | 1.9428  |     |  | 1.4236        | 2.0401  |     |  | -0.1700      | 2.0930  |     |  | 1.1676          | 2.1969  |     |  |
| 10 Sprayers                 | -0.1665     | 0.0661  | **  |  | -0.2215       | 0.0652  | *** |  | -0.2762      | 0.0751  | *** |  | 0.0210          | 0.0872  |     |  |
| 11 Plows                    | -0.0309     | 0.0675  |     |  | -0.1492       | 0.0539  | *** |  | -0.1304      | 0.0656  | **  |  | -0.2530         | 0.0871  | *** |  |
| 12 Oxen                     | -0.0357     | 0.0390  |     |  | -0.1090       | 0.0447  | **  |  | -0.1386      | 0.0432  | *** |  | -0.1869         | 0.0598  | *** |  |
| 13 Interaction: (11) x (12) | 0.0115      | 0.0081  |     |  | 0.0299        | 0.0064  | *** |  | 0.0246       | 0.0076  | *** |  | 0.0399          | 0.0107  | *** |  |
| 14 Motorcycles              | 0.0571      | 0.0937  |     |  | -0.0740       | 0.0940  |     |  | 0.0938       | 0.1062  |     |  | 0.0266          | 0.1244  |     |  |
| 15 Bicycles                 | -0.0223     | 0.0481  |     |  | 0.0081        | 0.0502  |     |  | 0.0067       | 0.0597  |     |  | -0.0661         | 0.0616  |     |  |
| 16 Carts                    | -0.2722     | 0.1683  |     |  | -0.3285       | 0.1586  | **  |  | -0.2371      | 0.1891  |     |  | -0.2439         | 0.2265  |     |  |
| 17 %MenLiterate             | 0.1524      | 0.3219  |     |  | 0.1795        | 0.3668  |     |  | 0.2369       | 0.4364  |     |  | 0.3077          | 0.4592  |     |  |
| 18 Interaction: (1) x (17)  | -0.6420     | 0.6777  |     |  | -0.7557       | 0.7784  |     |  | -0.7894      | 0.9265  |     |  | -0.1619         | 1.0336  |     |  |
| 19 %WomenLiterate           | -0.3121     | 0.3472  |     |  | -0.9498       | 0.3581  | *** |  | -0.5441      | 0.4350  |     |  | -0.5557         | 0.4616  |     |  |
| 20 Interaction: (2) x (19)  | 0.7095      | 0.6832  |     |  | 1.4396        | 0.6411  | **  |  | 0.8478       | 0.7622  |     |  | 0.7630          | 0.7118  |     |  |
| 21 Bambara                  | -0.6831     | 0.2450  | *** |  | -0.0120       | 0.2436  |     |  | -0.1826      | 0.2440  |     |  | -0.0971         | 0.4048  |     |  |
| 22 Senoufo                  | 0.2739      | 0.2653  |     |  | 0.4354        | 0.2653  |     |  | 0.1455       | 0.3154  |     |  | 0.2580          | 0.3837  |     |  |
| 23 Peulh                    | -0.3360     | 0.2920  |     |  | 0.2558        | 0.2876  |     |  | 0.2696       | 0.4165  |     |  | -0.5179         | 0.5090  |     |  |
| 24 OtherEthnic              | -0.2578     | 0.3019  |     |  | 0.4450        | 0.3425  |     |  | 0.8419       | 0.5640  |     |  | 0.2214          | 0.5364  |     |  |

**Significance Legend:**

\*\*\* = P<.01

\*\* = P < .05

\* = P < .10

**Table A.1 (cont'd): Fractional Multinomial Logit Results Pivoted off of CottonShare**

**Log pseudolikelihood = -480.02629**

**Obs: 334**

**Wald Chi^2: 2004.7**

**Prob > Chi^2: 0.0000**

|                      | Maize Share |        |    |     | Sorghum Share |        |    |     | Millet Share |        |    |     | Secondary Share |        |    |     |
|----------------------|-------------|--------|----|-----|---------------|--------|----|-----|--------------|--------|----|-----|-----------------|--------|----|-----|
|                      | Coef        | Rbst   | SE | Sig | Coef          | Rbst   | SE | Sig | Coef         | Rbst   | SE | Sig | Coef            | Rbst   | SE | Sig |
| 25 Year_2010         | -0.5653     | 0.1978 |    | *** | -0.4542       | 0.2465 |    | *   | -0.5979      | 0.3342 |    | *   | -0.7405         | 0.3814 |    | *   |
| 26 Village_Tonon     | 0.9747      | 0.2725 |    | *** | 0.6106        | 0.2563 |    | **  | -0.7074      | 0.3841 |    | *   | -0.0783         | 0.4351 |    |     |
| 27 Village_Kaniko    | 0.5786      | 0.2932 |    | **  | -0.1542       | 0.3035 |    |     | 0.3480       | 0.3453 |    |     | 0.7167          | 0.3618 |    | **  |
| 28 Village_Tryl      | 1.7042      | 0.4927 |    | *** | 1.9078        | 0.4567 |    | *** | 1.9018       | 0.4741 |    | *** | 2.5380          | 0.4777 |    | *** |
| 29 Village_Signe     | 0.8547      | 0.2521 |    | *** | 0.4771        | 0.2593 |    | *   | 0.8036       | 0.2853 |    | *** | 0.8558          | 0.3642 |    | **  |
| 30 Village_Gantiesso | 0.1488      | 0.2419 |    |     | -0.2929       | 0.2454 |    |     | -0.5200      | 0.2878 |    | *   | 0.6354          | 0.2998 |    | **  |
| 31 Village_Simona    | -0.2027     | 0.2302 |    |     | -0.5461       | 0.2639 |    | **  | -0.9598      | 0.2995 |    | *** | -1.1583         | 0.3760 |    | *** |
| Constant             | 0.1494      | 0.4564 |    |     | 2.4887        | 0.4740 |    | *** | 2.2872       | 0.4574 |    | *** | 1.8691          | 0.5614 |    | *** |

**Significance Legend:**

\*\*\* = P<.01

\*\* = P < .05

\* = P < .10

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